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Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt

WIND ENERGY MASTER PLAN

for

EGYPT

PHASE II

Final report

Containing

Assumptions, Scenarios, Analyses, Conclusions, and Recommendations

Prepared by

New and Renewable Energy Authority (NREA),
Cairo, Egypt

and

Risø National Laboratory
Roskilde, Denmark

December 1997

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1 Summary

This report contains elements of a *plan for development of long term utilization of the wind energy in Egypt*, elaborated during the elapse of phase II of the joint NREA-Risø project *Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt*, partially financed by the Danish Government through Danida, that was carried out during the period 1993 to 1997. The report is intended to serve as a source of background information, on which decision makers in concerned authorities and industries may decide future actions concerning the development of wind utilization in Egypt.

The study behind this report was carried out as a collaboration between Egyptian ministries, authorities, governorates, banks, and industrial enterprises; each with a particular knowledge and expertise. Thus, the information in the report should be regarded as a concerted effort to reach a consensus, that will constitute the bases for further studies and co-operation in this field.

Due to the limited resources and time available to the studies in phase II, not all assumptions and conclusions in this report may have found their final form, but they are presented in their current state, and may serve as the starting point and background for further, continuous planning studies.

The report contains a quantitative description of the Egyptian energy system, as it was according to statistics in year 1992/93 (the *Reference* year). Starting in this year, two main scenarios have been set up, one scenario named the *Base scenario* or *Expected scenario*, best described as a conservative (business as usual) estimate of the development of the Egyptian society, with a moderate wind penetration[1], the other scenario called the *Optimistic scenario*, characterized by a somewhat increased growth rate of GDP and a greater wind penetration; the time horizon of both scenarios stretches until year 2030. The description of the scenarios is based on existing plans where available, e.g., EEA's[2] detailed plan for development of the conventional power system; this, however, does not look beyond year 2017, and therefore the present study has used 2017 as a *midterm* year.

In the proposed plan for developing the utilization of wind energy, the generated electricity has been fed into the Egyptian power systems, both into the national grid linking most parts from the Aswan High Dam to Alexandria and Suez, and into isolated grids in remote areas where the local power system may have low capacity; the wind farm in Zafarana is an example of the first type, and communities like El Tor in South Sinai belong to the second category.

General assumptions

The driving force behind the *energy demand* in general and in particular, the *electricity demand* is a combination of the population and the gross domestic product (GDP); in both scenarios, it is assumed, that the growth rate of the population is 1.9% per year; in the Base case, the GDP is growing with 3.19% the first year, but with the rate decreasing to 3.07% during the period, and in the Optimistic case with 5.10% decreasing to 4.20% yearly.

In the two scenarios, wind energy has been introduced into the Egyptian power systems from wind farms, extended to 3250 MW in year 2030 in the Base case, and to 5500 MW in the Optimistic case, including both large farms as that at Zafarana and smaller ones in remote areas like e.g. South Sinai

In year 2030, the Zafarana wind farm is assumed to supply approximately 6% of the total electricity production in the national system in the Base scenario, and 8% in the Optimistic; the wind penetration increases slowly during the period, because although the wind production increases due to increased capacity, also the electricity demand increases in the regarded time horizon, mainly due to the population growth.

The development of the conventional power system follows EEA's planning, where old power units are substituted primarily by modern combined cycle, gas fired units and steam turbines.

As part of the study, the economy of wind power was compared to conventional production,

[1] Wind penetration = Wind produced electricity / Total electricity production

[2] Egyptian Electricity authority

and the influence of various components on the cost of a kWh was studied; e.g., the fuel prices, that are kept constant throughout the period analyzed in the two main scenarios, were - as part of the sensitivity analysis - given a yearly increase of 2% for comparison; in all cases, real prices without inflation were assumed. Also, the influence of domestic manufacture of wind turbines - partially in various amounts - was studied; a 40% participation (in money terms) was regarded reasonable in the first period - the balance of the WT being imported - and used in the calculations.

In particular, the wind penetration was varied in each scenario as a sensitivity analysis; the purpose was to check the interaction between wind and conventional production systems.

General conclusions

From the studies is concluded, that Egypt may take advantage of utilizing wind energy on a large scale, both as large wind farms connected to the national grid, and in smaller scale, as wind turbine installations in remote areas. Generally, both scenarios show that it will be beneficial to utilize the significant wind potential by implementing the proposed capacity; the simulations performed on the combined conventional and renewable power system (wind farms included) indicate, that within the accuracy of the models, the stochastic wind production may be absorbed without problems, even, if the wind penetration is 20%, and therefore, no problems are expected with the wind penetrations planned, that are below 10%.

Specifically, the benefits obtained for the Egyptian society are, among others[3]:

- A substitution in year 2030 of 3 - 5 thousand t.o.e.[4] conventional fuel per year by wind production; the saved fuel may be exported
- An annual saving of fuel costs amounting to 500 - 800 mill. £E in constant 1992-prices
- An estimated production cost of wind produced electricity ~13 pt/kWh compared to conventional produced ~8 pt/kWh with constant fuel prices and ~12 pt/kWh with slowly increasing fuel prices (2% per annum) (see note[5]); in these numbers, no capacity credit of savings in the conventional system due to the wind production in included
- A domestic manufacture of 40% of the wind turbines that will decrease the electricity production price by 20% compared to a 100% import
- A saved emission of harmful substances due to the decreased conventional power production, both of green house gases, and of corrosive and health threatening substances: CO_2 at the order of ~13 mill. tons and NO_x ~20 thousand tons every year around year 2030
- A benefit for the industrial sector from the proposed plan by participating in the production, both regarding the immediate revenue, and in the long term, by improving its capability in this field through adaption to the technology, thus creating basis for an export of advanced products and know-how; for this purpose, the industry may take advance of the technology centre in Hurghada
- The activity created by private investors, who are regarded as important in the

[3] Where a range of values is given, the low number refers to the Base case and the high to the Optimistic case, unless explicitly noted.

[4] Ton Oil Equivalent

[5] Comparing with equivalent European production costs, valid for the long term, it is found, that
- Danish off-shore turbines are estimated to produce at 0.30 - 0.40 DKK/kWh ~15 - 20 pt/kWh; these WTs are somewhat more expensive due to their placing, and their production is lower, both factors as compared to Egyptian conditions.
- Marginal costs on Danish, gas fuelled, combined cycle power plants are estimated to be 0.20 - 0.25 DKK/kWh, or ~10 - 13 pt/kWh. In 1995, the gas price from the European grid were ~1.25 DKK/cubic metre or ~32 DKK / GJ or 15 £E / GJ; in the calculations, the Egyptian gas price is fixed to 152 £E / metric tonne ~4 £E / GJ. Europe is using both domestic produced gas as well as imported gas from e.g. Russia, Algeria, and Norway.
- These numbers leads to the conclusion, that the Egyptian wind produced electricity costs seem reasonable, whereas the conventional production costs are very low due to fuel prices being lower than in Europe.

development of wind farms; they will look into this field with somewhat other interests than the public: the crucial point being the profit, obtained from the investment. The viability of private enterprises is closely connected with the conditions pertaining to the sale of electricity; the price paid by the utility should make the project attractive; calculations show, that in order to obtain a payback of the investments and operating costs corresponding to an internal rate of return of 15%, the price should be like that stated above, depending on the actual circumstances. This price is, however, not the only factor important to the private: it is obvious, that all legal and institutional aspects for private investors have to be clarified and - if necessary - reformulated in order to make many investors interested, e.g., in Build-Own-Operate-Transfer projects

- The social benefits associated with the manufacture, installation, operation, and maintenance of the wind farms as planned in this study; an increased employment of several categories of technicians and workers will take place, both in factories as well as in rural areas, where wind farms are established; the report contains some estimates of the man power needed, but the subject deserves more elaboration; thus a valuation of the benefits - and of those related to the environment - would quantify the increased welfare

Summing up, the conclusions may shortly be stated like:

Utilization of wind power is a realistic option in coming development plans; the benefits will appear in form of saved fuel, avoided costs, improved environment, new job opportunities, and possible future export of technology.

General recommendations

From the studies carried out by the participants in this project, the following general recommendation may be drawn:

The development plan for wind energy proposed in this report will contribute significantly to electricity production in Egypt and therefore, it is recommended both to include wind energy in national plans - and consequently in EEA's - and to continue NREA's activities in this field.

For particular items examined, the following recommendations resulted:

- Zafarana may technically and economically safe be extended from the current plans to 600 MW
- Three sites in South Sinai seem suitable for minor wind farms and should be given more attention, both concerning measurement of wind and power demand profiles, and assessment of production costs
- A subsidy of a few pt/kWh to wind produced electricity or a CO_2 tax of the same size on fossil fuelled production will equalise the two production methods; these options will encourage private investors
- Legal and institutional aspects pertaining to utilisation of wind energy should be examined, and if necessary, reformulated to encourage private investors
- The industry should be encouraged to prepare for an intensive participation in this field, e.g., by obtaining knowledge to recent advances in the technology and, where possible, to utilize the technology centre in Hurghada
- Financial resources of the order of 100 - 200 mill.£E should be made available in the coming years for investments in this field
- The planning procedures and the experience gained within the organization, that was set up during this project, should be utilized continuously to make regular updates of the development plan, useful in case of possible national or international interest for new specific projects
- A particular strategy should be formulated in order to exploit the wind resources

- Public relation should be strengthened and important results disseminated

It is underlined, that further work is a must in order to update the conclusions according to most recent knowledge and experiences gained.

2 Introduction

Wind energy can be considered as one of the main and most important sources of renewable energy. It has been utilized widely in many countries and reached a high degree of maturity and reliability. Presently, the total installed wind capacity world wide is almost 6500 MW, and the most popular and widely used wind turbine size is 500 kW, due to its technical and economical advantages; the wind turbine manufacturers already have larger models on line in the range 1000 - 1500 kW.

Certain regions of Egypt have high and continuous wind speeds, such as the Red Sea Coast, East Oweinat region, and Northern Coast; these facts encourage the planners to take wind power into consideration when planning for energy sources that will satisfy future needs.

As the contribution from renewables and - especially - wind energy has been included in the national Egyptian plans, it was decided by several countries and organisations to contribute in various ways to the development of this source of energy. Among these was Denmark, that supports the present project, which, in addition to the present Master Plan Component, comprises a wind park and a technology centre at Hurghada, and elaboration of a wind atlas for the Gulf of Suez.

In the resent five years, Egypt and Denmark have co-operated in the project: **Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt**, and as part of the project, the present report is issued, containing the findings of the planning studies carried out; thus, it represents the status of the long term planning concerning utilization of wind energy; it is, however, emphasised, that planning is a continuous process, in which the results and conclusions should be updated regularly in accordance with new knowledge and experiences. Thus, the report may serve as a reference document in the future planning procedure of wind utilization in Egypt.

The main objective of this report is to set up some scenarios for the exploitation of the abundant wind energy during the next decades with the aim to satisfy a substantial amount of the energy need, which also will result in fossil fuel savings and decrease of harmful emissions in addition to development of local production capabilities, and creation of job opportunities.

First, the report will review the background and the objectives of the project; next, the organisation is described, that carried out the studies; a large part of the report is devoted to a description of the studies: first, the assumptions underlying the calculations are given, next, the most important results obtained by the analyses are reported; further, the industrial options - relevant to the implementation of the proposed plan - are commented. Finally, the financial and economical factors, implied by the plan, are described.

The report's input data are based on many related studies and reports, and, of course, on planning studies carried out in other Egyptian authorities; conclusions and recommendations are extracted from reports prepared by the Working Groups and revised by the Co-ordination Group.

2.1 Background

An increasing welfare will most likely respond with a growing energy demand - an increasing consumption per capita, and a population growth will tend to accelerate the total demand for final energy. In Figure 1, Figure 2 the predicted development of the energy consumption is outlined for various cases.

Thus, the future trend, not particular to Egypt, will show an increased drain on the limited domestic energy resources, fossil as well as renewable. This will inevitably cause increasing prices on fuels and thus on electricity; a more extensive use of renewable energy sources may help to serve this extra demand, and, in addition, Egypt may have advantage both to export fossil fuels by substituting them with renewable energy, and, simultaneously, to improve the environment by a decreased pollution from fossil fired power plants.

There are ways to decrease the predicted growth of demand for fossil energy, which influence the presumptions and results of this study: one is to increase the efficiency of conventional power plants - that will affect the amount of saved fuel per kWh electricity produced by wind farms - another is to increase the efficiencies of processes and appliances using electricity - which will decrease the electricity demand, and affect the operation of the power production system, including the wind farms. In this study, these options have not been regarded in particular, as the focus has been fixed on utilization of the abundant wind resources in Egypt, which for several years has been regarded a potential supplement to other domestic energy resources like hydro and hydrocarbons.

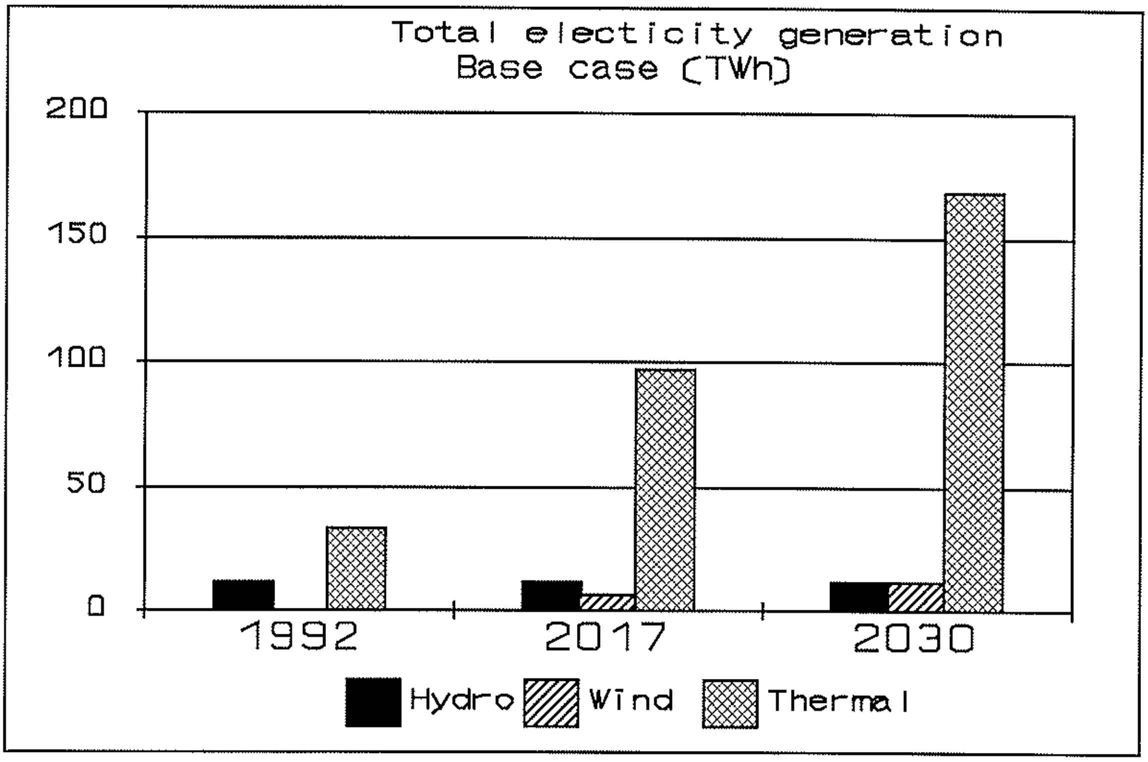

Figure 1 Electricity generation in Egypt (Base case)

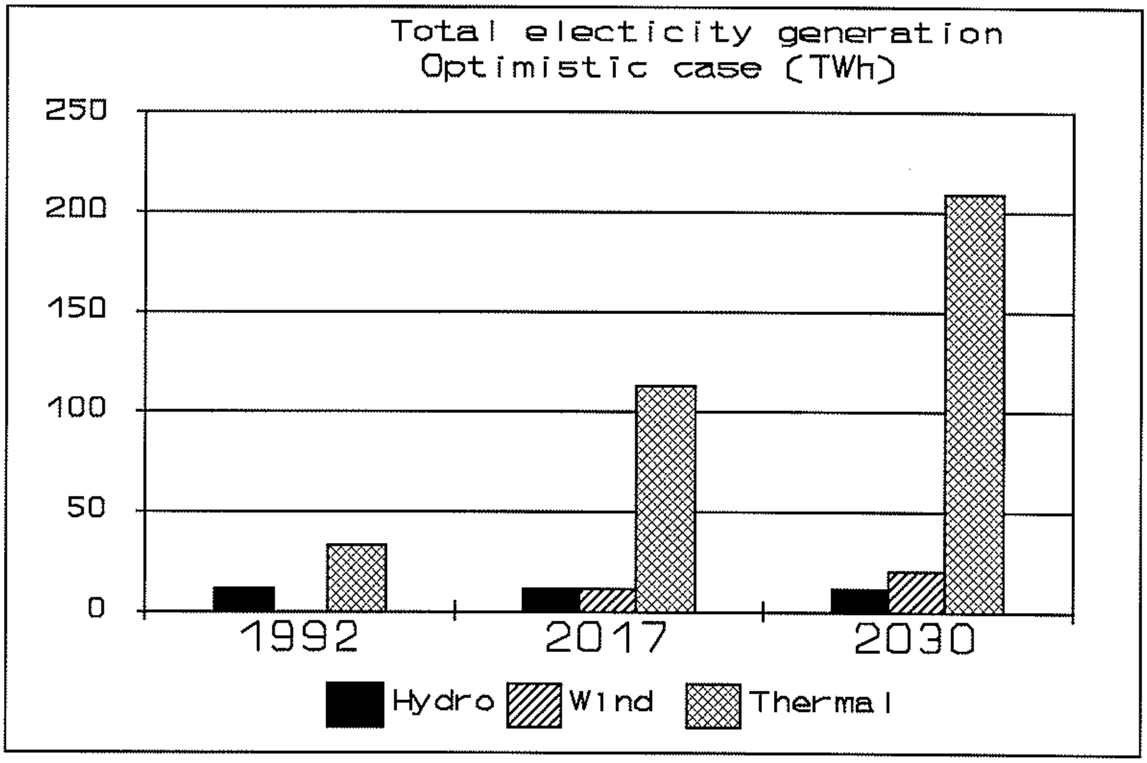

Figure 2 Electricity generation in Egypt (Optimistic case)

2.3 Project progress

During phase I of the project, which began in 1993, the set-up of the organisation - responsible for the preparation of the master plan - was accomplished. Further, two simulation models were transferred from Risø to NREA, adapted with preliminary data and relations to the Egyptian environment, and in order to understand and to use the models, training of the Egyptian teams were carried out in Egypt and in Denmark.

After completion of Phase I in April 1995, the work was carried on at a low pace, a large part being devoted to the preparation of the revised proposal for Phase II. The proposal was formally accepted by Danida in May 1996, and since then, the work has continued at a high activity level, the major task being compilation of information and data for analysis and preparation of the present report; the efforts were carried out by the full organisation set up in Phase I.

In Phase II the Working Groups finalized their reports, and the model groups analyzed the selected scenarios, both during missions to Risø and at NREA. The results of these studies are presented in the following.

2.4 Survey of contents

The present report contains the most updated analysis of the information, on which conclusions and recommendations are based, and covers the following subjects:

- a main report with
  - principal assumptions
  - selected scenarios
  - principal results
  - conclusions
  - recommendations
- appendices with details of
  - the project set-up
  - results attained by the Working and Model groups

This report is written jointly be the Egyptian and the Danish participants of the project; a large part of the analysis leading to the conclusions and recommendations is the result of a joined effort between the Egyptian and the Danish teams, whereas all data are provided by Egyptian sources.

The Egyptian contributions to the project were carried out by:

-	Eng. M. A. El Karmalawi	NREA
-	Eng. Laila Abd-El Kawi Saleh	NREA
-	Eng. Laila Georgi	NREA
-	Eng. Amira M. El Mallah	NREA
-	Eng. Ashour Abd El-Salam Moussa	NREA
-	Eng. Yahia Abd El-Ghany Salem	NREA
-	Eng. M. Akmal Mahmoud	NREA
-	Econ. Adel Mahmoud Ibrahim	OECP
-	Eng. Nagy El Gawly	EEA
-	Eng. Manal Abd El Hakeem	EEA

The Danish contributions were prepared by:

-	Peter Skjerk Christensen	Risø	Editor
-	Henrik Klinge Jacobsen	Risø	
-	Lars Henrik Nielsen	Risø	
-	Klaus Skytte	Risø	

- Niels Juhl Thomsen Risø[6]

In addition, members of the Co-ordination and Working groups have contributed substantially to the study, e.g., by propose amendments or giving comments to assumptions, calculations, and this report.

[6] During first phase of the project, presently not employed at Risø

3 Objectives

The overall objective of the project to which the long term plan is related, is "to improve the capacity of GOE/NREA to implement utilization of wind energy equal to 5% of the total power consumption in year 2005[7]" in Egypt; thus wind energy will substitute conventional fuels.

In this part of the project - the Master Plan Component - a long term plan is set up. The purpose of a long term plan for utilizing wind energy is to provide decision makers with information that gives a solid basis, on which proposals for initiatives to introduce a wide spread use of this technology in Egypt can be taken.

Consequently, this report contains analyses and recommendations regarding:

- introduction of wind energy in various amounts in the Egyptian power system
- benefits of the use of wind power
- economic constraints and consequences
- institutional matters important to realize the intentions in this report

The organization, with the methods and tools set up in this project, may in the future update the knowledge and information regularly, determined by actual needs, e.g., when the underlying assumptions are changed considerably.

The objectives of the Master Plan Component is for operative purposes split in *Long term* and *Immediate* objectives.

3.1 Long term objectives

In general, long term objectives for planning comprise elements which are regarded beneficial for society in the long run, e.g. an increased social welfare. In the present context, Egyptian planning contains an intention to substitute parts of the fossil fuel supply with renewable energy sources aside from the hydro power - and the abundant wind resources, especially at the Red Sea coast, are candidates. Thus, these objectives may comprise, in necessary details, description of ways to reach the goals set forth in the national plans.

Therefore, the Master Plan report must:

- contain the goals to be reached, e.g., the wind penetration
- describe the assumptions, e.g., the electricity demand
- outline the sites and sizes of recommended wind farms
- estimate the necessary investments
- point out constraints to reach the goals and possible ways to relax these
- quantify the benefits of carrying out the plan in terms of
    - economy
    - social impacts
    - environmental consequences

3.2 Immediate objectives

The immediate objectives concern the goals to be reached inside a short span of time. Among these are:

* To make the Egyptian society aware of the benefits of using wind energy
* To include items of this study into other planning, e.g., the national five year plan for years 1997 - 2002
* To develop the Egyptian industrial capability and capacity to manufacture wind turbines

7 Demonstration and development of technology and planning in the wind energy sector in the Arab Republic of Egypt, Agreement for Consultancy Services, April 1992.

4 Relation to other planning

The aim of this study is to contribute to the national, regional, and other planning activities in Egypt, and the contents of this study must obviously be consistent with:

- national five-year plans
- plans, studies, and recommendations of various authorities like
  - EEA
  - OECP

During the process, this aim was partly solved by the participation of representatives of relevant ministries, authorities, and other organizations in the Co-ordination and Working groups, in this way establishing a formal forum, where information and view-points could be exchanged.

Refer to appendix A for a listing of the members of these groups.

5 Organisation of the work

The process used to elaborate the master plan involved many authorities and institutions, and the work itself was lengthy and expensive. Therefore, the establishment of the organisation, the definition and specification of the various tasks, and the delegation of these to working groups, were crucial points.

The set-up of the organisation and formulation of their responsibilities were major tasks during the First phase of the project. In the Second phase, the organisation continued the study in the Working Groups as well as in the model groups, and results of the studies are compiled in the present report.

The Egyptian organizations have the responsibility for the information and data used in this study, whereas Risø's responsibility concerns the back-up of the preparation of the report, including updates of the models, when needed, to adapt them to the particular Egyptian energy system and data representation.

In Appendix A, a detailed description of the organization is given.

5.1 Co-ordination and Working Groups

The principal task of organizing and setting forth the goals to reach in the master plan studies is the responsibility of the Co-ordination Group. It is composed by ministerial decree of high ranking representatives of relevant ministries, authorities, and other organizations including industry, totalling 11 members, meeting once a month.

To carry out the detailed studies four Working Groups have been established, the member of which are representatives of relevant and affected organizations, grouped according to their specified tasks, namely:

Working Group I	Institutional responsibilities and legal matter
Working Group II	Wind industry and marketing
Working Group III	Investment and finance
Working Group IV	Siting and Application

The intention was, that the WGs should meet, when necessary, typically once a month, during the busy period.

5.2 Secretariat

A secretariat to take action on all practical problems, is formed inside NREA, which pointed out its members.

The preparation of the master plan is a joint effort of NREA and Risø. NREA has knowledge of all information concerning data and institutions particular to Egypt, while Risø has a long experience in preparing energy and master plans, for Danish as well as foreign clients; Risø contributes with institutional back-up and advices, both regarding the process of preparing the report, to run the models, and to analyze results.

5.3 Model groups

To analyze the scenarios, two model groups were formed, one to take care of the overall calculation of technical and economical consequences, the other to carry out simulations of the time depending production by wind turbines and their influence on the conventional power producing system.

Risø trained the model groups in the correct use of the models, which were adapted to the Egyptian data and energy system, in order that the Egyptian model groups could run the models independently.

6 Assumptions

The study concerns future states of the Egyptian society, especially introduction of large scale wind generated electricity into the energy supply system, and therefore, forecasts are necessary for all quantities which influence energy related quantities, represented in the calculations. Where possible, prognoses from other studies have been used, but in some cases, a few have been selected inside the project to study the sensitivity of overall results to these particular variables. Basically, the are two groups of assumptions:

* quantities, that describes the Egyptian society (demographic and economic variables)
* quantities related to those parts technical systems, that are relevant to the wind power

Scenarios

A well known technique to handle the uncertainties connected with estimates of future states, is to run a number of scenarios and sensitivity analyses, i.e., calculate certain state variables in selected years. In this project, two **scenarios** are studied, describing the future:

* the **basis scenario**, where all variables follows other planning strictly as far as possible; as the scenario represent highly possible future states, it is often referred to as "Business as usual" or "Expected" scenario
* the **optimistic scenario**, where the principal economic parameter: the growth rate of GDP, is assumed to be higher than in the basis scenario, giving higher electricity demand, and thus possibilities to install more wind capacity with acceptable influence on the conventional power system

The calculations are performed inside a certain **time horizon** but not all years are simulated in detail, only the **reported years**. In this study of future conditions in Egypt, it has been decided to focus on three years:

* the **reference year 1992**, used as the starting point, selected as the most recent year - at the time, the study was initiated - where all data were available, needed for the models. In addition, this year serves as a calibration point for the models
* the **mid term year 2017**, selected because EEA presently has a planning horizon until this year, which thus is taken into consideration
* the **long term year 2030**, selected in order to be able to study the conditions in the long term. Data for this year have been extrapolated from the present state based on information provided by OECP and used in other studies

Although years between the reported are not calculated in details, all conclusions drawn from the results must assume, that the development in these years follows a reasonable path, so if necessary, it is possible to calculate any year to the same extend as the three reported years.

In order to examine, if certain variables have decisive influence on the outcome of the calculations, they are studied in some detail by varying their values, one at a time, inside certain limits. These calculations are referred to as **sensitivity analyses**, and will described in some details.

6.1 Principal assumptions for the calculations

6.1.1 Data categories used for calculations

In order to simulate the Egyptian energy system, a large amount of information and data are needed; part of the data is a collection of relevant data valid for the present situation in Egypt, whereas other, used for the future state - the scenarios - are extrapolated by means of trends of various parameters. The data for the present state are important, because the confidence of the future state relies on the accuracy of the present data.

The data for the reference year are copied from existing statistical information, whereas data for the scenario years are copied from existing planning studies or - where not available - estimated, especially for the sensitivity analyses. The following gives an overview of the data necessary:
For the reference year the following data are needed:

- demographic data: population, number of persons per household, etc.
- technical data
  - power load or demand data
  - existing power plants and their characteristics
  - existing transmission systems
- economic data
  - fuel prices
  - O&M costs
  - sale prices of electricity
- environmental data
  - emission factors for SO_2, NO_x, N_2O, CH_4, and CO_2 for each type of power plant

Some important quantities are given in Table I and Table II.
For future states - the scenario years - projections are needed for the variables above, but also for:

- technical data
  - expansion plans for power plants and wind farms
  - possible sites for wind farms and their wind resources
  - foreseen technical developments
- economic data
  - projections of specific investments
  - projection of other relevant economic parameters like interest rate

Examples are given in Table I - Table V

6.2 Scenario assumptions

In the following the assumptions used to set up the scenarios, are tabulated.

6.2.1 Overall parameters

Some of the parameters that control the energy demand, are given in Table I. The data concern the economic and population growth, the discount rate, and - as the transport energy demand is exogenous in the present model, a forecast of the electricity demand by this sector.

Another important set of assumptions are the future fuel prices, that determine the power production costs, and thus the economics of wind power; in Table II the prices are listed - without taxes etc.

The *Industrial energy price* is the average price payed by industry; the price is a weighted mean of coal, oil, and gas prices, the weighting factors, according to the mix of power plants, being:

Fuel	1992	2017	2030
Coal	11%	11%	11%
Oil	59%	39%	29%
Gas	30%	50%	60%

It is seen, that all prices, apart from the industrial energy price - are presumed to be constant in real terms.

Table I Principal assumptions

	Reference year	Base scenario Growth rate % / year		Optimistic scenario Growth rate % / year	
Item	1992	2017	2030	2017	2030
GDP Egypt (bill. LE)	131.0	3.19	3.07	5.10	4.20
GDP Agriculture (bill. £E)	21.7	3.30	3.00	4.30	4.30
GDP Construction (bill. LE)	6.7	4.00	3.70	6.40	5.20
GDP Industry (bill. LE)	21.7	4.40	4.00	5.50	4.90
Service, Elect demand, mio. kWh	3155	4.60	4.60	5.50	6.00
Transport, energy demand, mio. kWh	70228	2.70	2.70	4.80	5.40
Population (million)	56	1.73	1.29	1.73	1.29
Discount rate (%)	4.50	0.00	0.00	0.00	0.00

Table II Energy prices in real terms

	Reference year	Base & Optimistic Scenario	
		Growth rate	
Fuel prices (LE/Ton)	1992	2017	2030
Gasoil	480	0.00	0.00
Fueloil	130	0.00	0.00
Kerosene	504	0.00	0.00
LPG	200	0.00	0.00
Gasoline	1260	0.00	0.00
Natural gas	152	0.00	0.00
Coal (power plant)	170	0.00	0.00
Coal (industry)	170	0.00	0.00
Industrial energy price £E/GJ	3.72	0.23	0.20
Electricity price £E/kWh	0.12	0.00	0.00

6.2.2 Power system parameters

In the following Table III, data for the power system needed for the calculations are given in some details. All data refer at the production level.

The conventional plants are grouped as follows:
- steam units
- combined cycle plants
- gas turbines

- pumped storage plants

The renewable production is grouped like
- hydro power plants
- wind energy plants
- solar / wave plants

ES[3] simulates these plants and calculates the equivalent number of full load operation hours for each group, which in turn are used by BRUS II to compute fuel demands, emissions, and economic quantities.

Table III Installed capacities in scenario years.

		Reference year	Basis	Scenario	Optimistic	Scenario
Plant type	Unit	1992	2017	2030	2017	2030
- Hydro	MW	2715	2805	2805	2805	2805
- Wind	MW	0.4	1800	3250	3080	5500
- Steam turbine	MW	6180	11718	22833	14155	28562
- Combined cycle	MW	283	5021	9000	5021	9000
- Gas turbine	MW	2222	2044	2000	2044	2000

The conventional power plants consuming fossil fuel are:

- steam turbines
- gas turbines
- combined cycle plants

Due consideration is taken to the age of existing plants (and thus their efficiency) of the various plants, and within each group, old plants are decommissioned and new are brought on line, all according to the current planning at EEA.

6.2.3 Wind power system parameters

In Table IV, data for setting up wind power plants are given in more details. First, the capacity of the various types of wind turbines are given. From the total capacity, the number of wind turbines are found. This number is important for the manufacturing process, for preparation of the infrastructure, and for the erection of the wind turbines. From this table, the manufacturers may estimate the necessary capacity of production facilities, etc.

Table IV Installed capacity and approx. number of WTs established yearly

Zafarana

	Base scen.		Opt. scen.			Base scen.		Opt. scen	
Year	Cap.	Num.	Cap.	Num.	Year	Cap.	Num.	Cap.	Num.
	MW					MW			
1994	3	6	3						
1995	1.8	4	1.8		2013	80	100	200	200
1996	0	0	0		2014	80	100	200	200
1997	0	0	0		2015	80	100	200	200
1998	30	60	30	60	2016	80	100	200	200
1999	50	100	50	100	2017	80	100	200	200
2000	60	120	120	240	2018	120	180	360	360
2001	60	120	120	240	2019	120	180	360	360
2002	100	200	200	400	2020	120	180	360	360
2003	100	200	200	400	2021	120	180	360	360
2004	100	200	200	400	2022	120	180	360	360
2005	100	200	200	400	2023	120	180	360	360
2006	100	100	200	200	2024	150	210	420	420
2007	100	100	200	200	2025	150	210	420	420
2008	80	100	200	200	2026	150	210	420	420
2009	80	100	200	200	2027	150	210	420	420
2010	80	100	200	200	2028	150	210	420	420
2011	80	100	200	200	2029	150	210	420	420
2012	80	100	200	200	2030	150	210	420	420

During the past years, the size of WTs has increased gradually, reflecting the technical development. The first machines installed in Egypt had capacities ~50kW, whereas recently (1997) published Danish data show, that several manufacturers market 1.5MW machines.

In the table, that concerns both scenarios, the size of wind turbines used to calculate the number of wind turbines installed yearly, has been chosen as 500kW until year 2005, and thereafter 1MW, taking into consideration the time needed to transfer the necessary technology. It should be noted, that the actual wind capacity for a given year depends both on new capacity installed that year, and on those installed earlier, but decommissioned due to age, as the anticipated life time of the machines is ~20 years.

In Table V, a number of economic data concerning the economic data for wind turbines; however, it is underlined, that during the time horizon regarded, WTs with larger capacities are installed, because they will be more economic.

Table V Example of economic data for a 225kW wind turbine.

Cost item	Part of investment	Fully imported	40% local
Investments	%	1000 £E	1000 £E
Wind turbine FOB		816.0	718.1
Customs	16	130.6	78.3
Insurance	2	16.3	9.8
Price CIF		962.9	806.2
Transport & installation	5%	48.1	40.3
Foundation & civil works	7	67.4	56.4
Cables & Elec. works	7	67.4	56.4
Spare parts	2.5	24.1	20.2
Total per WT (1)		1169.9	979.5
Running costs		1000 £E/year	1000 £E/year
Operation & Maintenance	5	58.5	49
Overhauls (2)	15	175.5	146.9

Notes: (1) in a wind park
(2) after 10 years

6.2.4 Environmental parameters

The emission of various chemical compounds from combustion processes are calculated using average emission factors, that depend on the fuel (or fuel mix) and the combustion process. As the calculations do not consider each individual power plant or boiler unit but aggregated groups, the emission factors are given as averages for the same groups, knowing that this is a simplification.
In sec. 11.2 the factors are given related to the fuel consumption.

6.3 Findings by the Working Groups

The four working groups established in the Master Plan organization were presumed to analyze specific subjects within their particular field, and had, according to their members' experience, a thorough knowledge to the tasks set up; their job was finalized with reports exposing findings and recommendations. In appendix B - E reviews are given, and below the most important conclusions are stated, which have immediate influence on the Master plan report.

6.3.1 Institutional & Legal Aspects (WG I)

The subjects presumed to be studied by WG I are important for a wide establishment of wind farms, especially in order to expose those conditions, according to which private investors have to act and which influence the economic viability of a particular project; thus, the WG should compile and comment conditions of legal and institutional character, which the investors must observe.

However, no activity was reported in this WG, ref. appendix B.

6.3.2 Wind Industry & Marketing (WG II)

The subjects presumed to be studied by WG II concern, among other, the possibility to engage Egyptian industry in the manufacture of wind turbines, which otherwise will be imported. Such an engagement will, in addition to the economic profit, increase the industry's capability, will create jobs, and may lower the costs of the WTs.

The WG pointed to various areas, in which the industry can participate, namely the production of the machines, the establishment of the sites, and by technical support and maintenance. It is estimated, that presently some 30% of a WT (in money term) may be produced locally, but this part may be extended by technology transfer, depending on the actual production volume. Further, the most likely components to be produced in Egypt are listed along with candidate companies to execute the tasks.

Finally, an estimate of the man-power needed to establish a given WT is given, summing up to several thousands of jobs in order to manufacture and operate WTs.

For further information, refer to appendix C.

6.3.3 Investments & Financing (WG III)

One important question, that has been assessed and reported by this WG, concerns the production price of electricity, which may be expected, taking investments, operating costs, and interest rates into account - among other factors. This price is of primary interest, especially for private investors, considering establishment of wind farms, but also to the public investor, who may earmark funding for new projects in this field.

The analysis was concentrated on

- levelised production cost
- selling price at given internal rates of return
- required investments
- necessary financial resources

for public as well as private investors. The calculations show, that a levelized production price at Zafarana typically will be in the range 10 - 13 pt/kWh, and in South Sinai 20 - 40 pt/kWh, the difference caused by the different wind conditions. The size of the WT does influence the price, mostly in South Sinai: larger machines infer decreased production price.

Further, the WG analyzed the selling - that price, which the utility should pay the investor in order to give an attractive Internal Rate of Return of a particular project. Choosing an IRR = 13.5% for public and 15% for private investors, the selling price must be in the range 9 - 15 pt/kWh at Zafarana and 22 - 38 pt/kWh at Dahab in South Sinai. Consequently, the utility has to pay prices in these ranges during the years corresponding to the life time of a WT, typically 20 years, in order that e.g., a BOOT project would attract possible investors.

Finally, the total yearly investments needed to implement the wind parks with capacities as described elsewhere in this report, have been estimated until year 2005.

For further information, refer to appendix D.

6.3.4 Siting & Application (WG IV)

The main task for this working group is to identify sites, which may be of interest for utilization of the wind energy, and to propose plans for evaluation of the availability of wind, e.g., pointing out candidate sites for further study of the wind regime.

The WG's report notes, that an extensive measuring program is operating in the following regions:

- The Red Sea coast (14 stations)
- The North coast (5 stations)
- Sinai (15 stations)
- New Valley (10 stations)

Further, the report notes, that a number of demonstration projects, both grid connected and wind-diesel systems, have been operating for several years, and may provide useful information, when assessing new projects.

Finally, the South Sinai region was examined, and a number of localities was identified, which may be subject to future development, and therefore probably may show increased electricity demands; three of these: Dahab, Ras Sedr, and El Tor, have reasonable average wind speeds, and wind power production costs comparable to conventional production, and they are recommended for further study.

For further information, refer to appendix E.

7 Analyses

In this section the results from the runs of the main scenarios and other calculations are presented; in addition, the section contains sensitivity analyses, where selected quantities are varied in order to estimate the robustness of the assumptions given in sec. 6, on which the calculations are based. As described in sec. 6, the two main scenarios are considered, each for two years: 2017 and 2030; the following tables show selected numbers under these headings; more information may be found in the appendices and references.

7.1 Selected sites

The sites regarded in the calculations are selected based on information on wind resources and on plans to expand the use of renewable sources at the coast of the Suez Gulf, and also at remote sites, where the demand for electricity is planned to increase. The following sites seem to be promising candidates for wind farms:

- Zafarana - which is situated in a region with extremely good wind conditions and with access to the national grids
- South Sinai - where, among several remote areas that have been analyzed, the following three seem promising:
    - Dahab
    - Ras Sedr
    - El Tor

It is remarked, that in all simulations, that need time series for electricity demand and wind speed, data for the Zafarana region have been used due to unavailability of data from other sites; this was the case for the three remote areas. Where only yearly averages are needed, the best available values are used. In the simulations, all wind turbines are considered grid connected to a system with characteristics like the national grid; this is a simplification, which may be improved, when more data are available.

7.2 Technical and economic results

Simulations have been carried out with the BRUS II and ES3 models, and in the following, results are given for the sectors represented; more detailed tables are presented for the power and wind sectors. The economy for a single wind turbine as well as for wind parks was examined. A description of the models used for the simulations, their interdependence, and selected results are given in appendix F and G.

7.2.1 Overall results for the total energy system

In this section, the energy consumption in the Egyptian society is shown, grouped sector wise for households, production (industry), transport, and power production; the final energy consumptions are given in Table VI, split in the various fuels; note, that "Other petroleum products" are hydrocarbons used for non-energy uses like lubricants, asphalt, input for chemical processes, etc. They do not contribute to the energy supply but do emit pollutants when used.

Table VI Final energy demand

Final energy demand [PJ]	Reference	Base scenario		Optimistic scenario	
	year	Growth rate %		Growth rate %	
	1992	2017	2030	2017	2030
Petroleum product	662.60	3.02	1.25	5.69	3.97
Natural gas	134.34	4.21	8.18	5.43	9.28
Electricity	134.45	3.86	3.81	4.61	4.52
Other petrol. products (*)	388.36	3.85	0.86	5.86	2.70
Total final consumption	971.79	3.37	3.38	5.50	5.00

(*) Non-energy oil products (lubricators, asphalt, etc.)

Overall data for that part of the power system, that is connected to the national grid, are given in Table VII; the total capacity includes the wind farm at Zafarana, whereas the remote areas are not included. The data shown comprise expansion plans for the conventional power capacities according to EEA, and an expansion of the Zafarana wind farm as given in sec. 6. The reserve capacity is seen to be rather high, the reason being, that new efficient combined cycle plants are planned, but existing steam units not removed from the stock of active plants. The base scenario has a higher reserve than the optimistic due to the increased electricity demand in the latter scenario without any extra conventional power plants being planned.

Table VII Power capacity and demand

Total power sector (*)	Reference	Base scenario		Optimistic scenario	
	1992	2017	2030	2017	2030
Total Capacity (GW)	11.4	32.5	56.5	33.8	58.8
Total Demand (GW) (+)	8.9	19.4	33.2	21.5	38.3
Reserve capacity (GW)	2.4	13.1	23.3	12.3	20.5
Reserve capacity(%)	22	67	70	57	53

(*) *Connected to the national grid*
(+) *Demand capacity factor 6291 h from year 2017*

7.2.2 Selected results for the electricity sector

In the following tables, results from simulations of the power sector are listed. First, overall electricity production data, grouped by technology, are given in Table VIII including total fuel consumption. In Appendix G, some details are given of results from ES3 and BRUS II simulations.

The total generation is listed in Tables VII and VIII, whereas Table IX focuses at the contribution from renewable resources; the wind power is seen to provide ~6% in the base case, and ~8% in the optimistic, both relative to the conventional production. The wind penetration is higher in the optimistic scenario due to the fact, that although the demand and consequently the wind power

Table VIII Overall scenario results concerning power sector

		Reference year	Base scenario		Optimistic scenario	
Quantity	Unit	1992	2017	2030	2017	2030
Electricity generation						
- total	10^9 kWh	44.6	115	192	136	241
- by conventional fuels	10^9 kWh	33.4	97	169	113	210
- by hydro	10^9 kWh	11.2	12	12	12	12
- by wind	10^9 kWh	0.0	6.5	12	11	20
Fuel consumptions for power production	mill.t.o.e.	7.9	21.5	37.7	25.3	47.5

capacity are increased, the capacity of the conventional power production system is kept unchanged. The simulations with ES3 showed, that according to its representation, the conventional power plants can absorb the time varying production by wind without any problems.

Table IX Production by renewable sources

Power system connected to national grid	Reference year	Base scenario		Optimistic scenario	
Share of capacity	1992	2017	2030	2017	2030
Total capacity installed (GW)	11.4	32.5	56.5	33.8	58.8
Wind share (%)	0	6	6	9	9
Hydro share (%)	24	9	5	8	5
Thermal share (%)	76	85	89	83	86
Share of electricity production					
Total energy produced (TWh)	62	115	192	136	241
Wind share(+) (%)	0	6	6	8	8
Hydro share (%)	18	10	6	9	5
Thermal share (%)	82	84	88	83	87

(+) Wind penetration

Finally, estimates of the production costs as calculated by the models are given in Table X, both for wind farms connected to the national and to remote systems. The table shows - for the Zafarana wind farm - that the costs of conventional production are less than for wind production; for the conventional plants, the fuel costs dominate the production costs, whereas the investments and overhauls dominate the production costs for wind farms. The difference is small, which underlines the

Table X Power production costs

Total annualized costs [£/kWh production]	Reference year	Base scenario		Optimistic scenario	
Zafarana	1992	2017	2030	2017	2030
Wind Power	0.13	0.13	0.13	0.13	0.13
Hydro Power	0.10	0.10	0.10	0.10	0.10
Thermal Power	0.06	0.08	0.08	0.08	0.08
South Sinai (Wind only)					
Dahab (*)	0.21				
El Tor (*)	0.29				
Ras Sedr (*)	0.19				

(*) 500 kW wind turbines, 60% import

importance of reasonable assumptions, e.g., the fuel prices estimated for the future, but assumptions concerning the percentage of the wind turbines, that may be manufactured in Egypt, are also crucial; small changes of the prognoses alter the balance between the two production costs; this point has been studied in sec. 7.3.

7.2.3 Savings due to wind power

In the following Table XI, data concerning the savings due to introduction of wind power are given. The savings are calculated by "substituting" the wind power production by an equivalent conventional production; as an example, production with steam turbines has been assumed. The saved O&M-costs have not been regarded, because sufficient reserve capacity has to be on-line in order to cope with varying production from wind farms.

7.2.4 Production categories

In the following graphs the contribution to the power production from the various technologies and fuels are illustrated, Figure 3 for the reference year, Figure 5 the Base scenario, and Figure 7 for the Optimistic scenario. The wind penetration is higher in the latter case.

7.2.5 Avoided emissions

The conventional power plants will produce various chemical substances by the combustion process; some of the emission types are harmful to the environment - SO_2, NO_x - others may contribute to the global warming - CO_2, NH_4. Substituting power production based on conventional fuels by electricity generated by wind turbines and other renewable resources will decrease the emissions.

Flue gas cleaning equipment may be installed in the exhaust or chimney; however, the calculations assumes, that no flue gas cleaning is installed on the power plants.

All sectors using energy are represented in the calculations in order to illustrate the power sector's contribution to the total emissions and the influence of renewable energy sources.

The calculations show, that the power sector's contribution to the total emissions in year 1992 depends strongly on the emission type. Presently, this sector is responsible for a great part of the CO_2 and SO_2 emissions; in the future, the SO_2 emission decreases markedly due to a shift to natural gas,

Table XI Savings due to renewable energy substituting conventional

Savings due to renewables	Reference year	Base scenario		Optimistic scenario	
Saved fuel					
- *Savings in mill. t.o.e.*	1992	2017	2030	2017	2030
Wind Power	0.4	1.56	2.82	2.67	4.77
Hydro Power	2.46	2.62	2.76	2.62	2.76
- *Savings in % of conventional fuel consumption*					
Wind Power	0.0	7.3	7.5	10.6	10.0
Hydro Power	20.4	12.2	7.3	10.4	5.8
- *Savings in PJ*					
Wind power	0.02	65.4	118.0	112.0	200.0
Hydro power	102.99	110.0	116.0	110.0	116.0
Saved costs (Mill.£E)					
Wind power	0.1	263.6	475.9	451.0	805.0
Hydro power	415.1	442.4	466.0	442.0	466.0
Total	415.2	705.9	942.0	893.0	1271.0

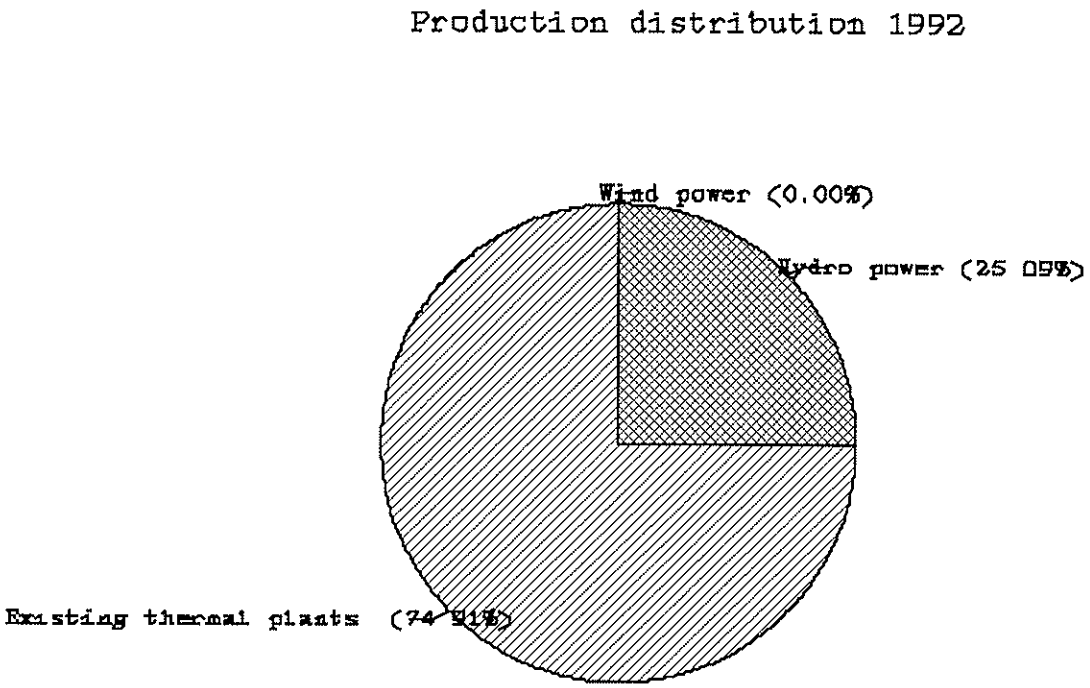

Figure 3 Production by plant categories in the reference year

while CO2 emissions are not influenced that much. Concerning NOx and NH4, the power sector is responsible for a minor part only.

These trends are seen on Figures 6 - 17. On the graphs, the total emissions from the sectors represented in the calculations are shown together with the savings due to power production be wind turbines. The wind power gives a marked reduction, especially of the green house gas CO_2.

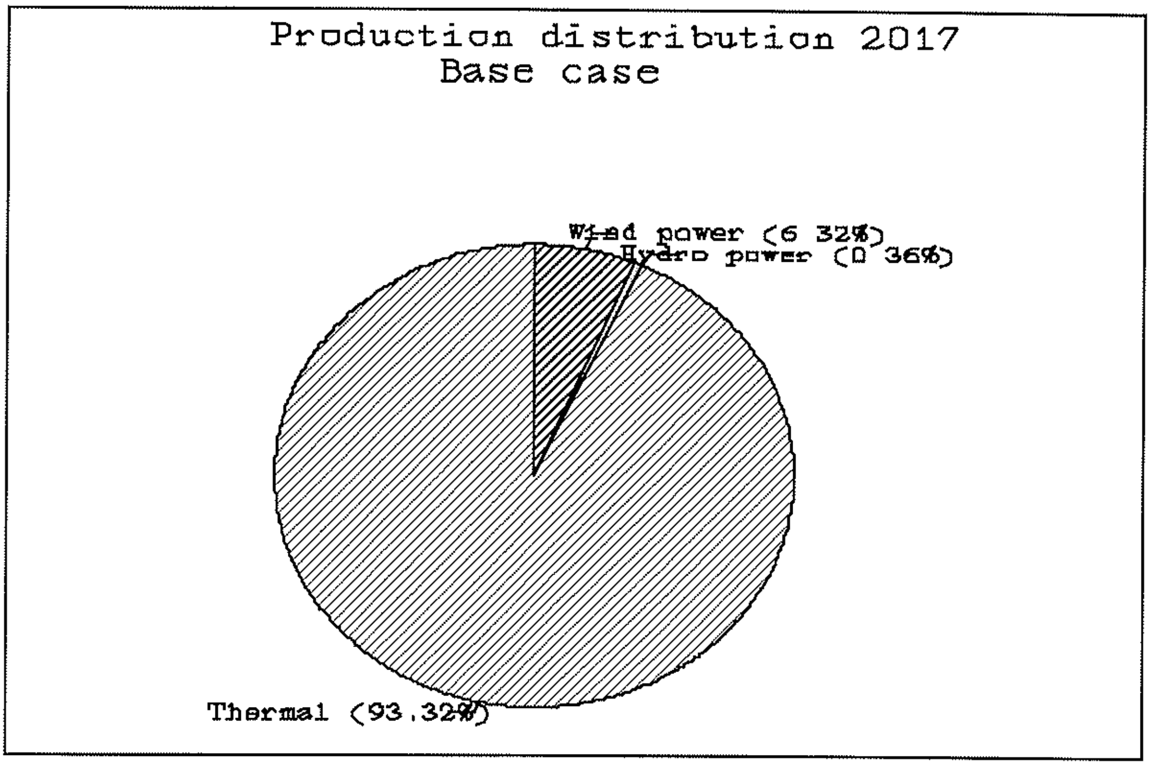

Figure 4 Production by plant categories, Base scenario

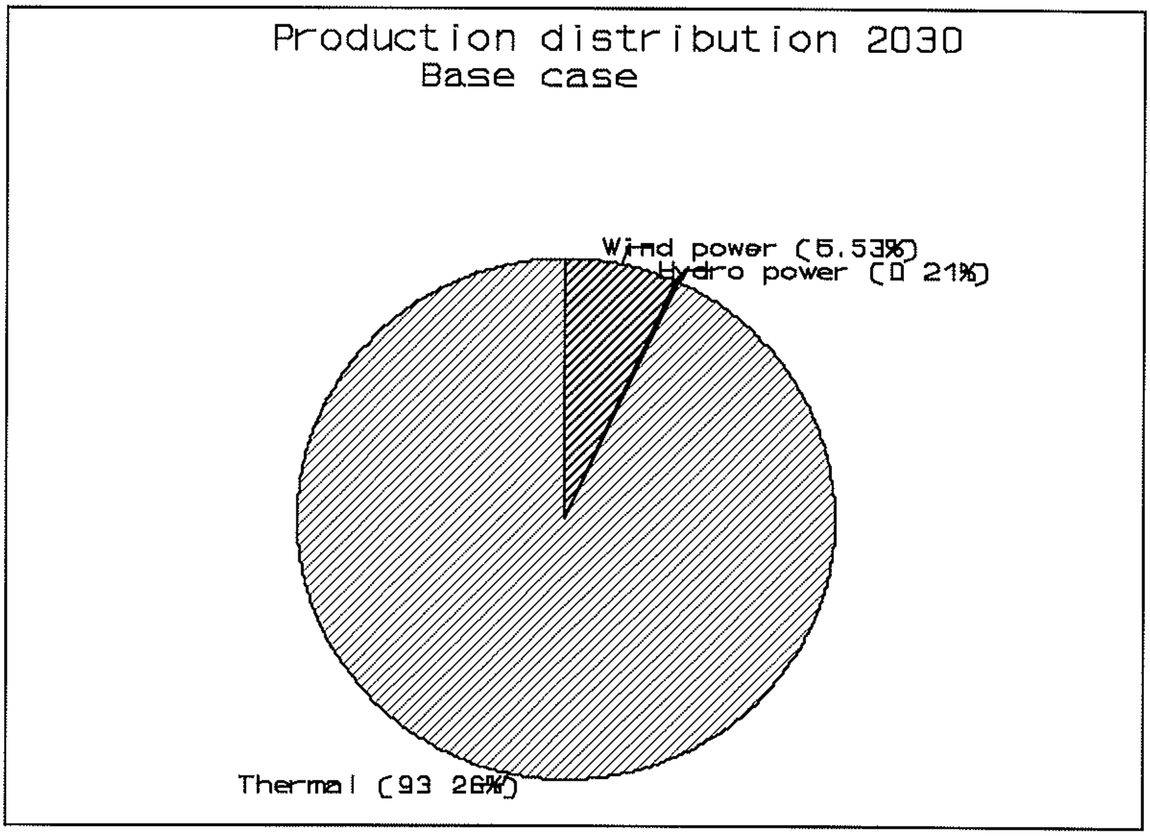

Figure 5 Production by plant categories, Base scenario

In the production system in the Base scenario is outlined with the percentages of each plant category.

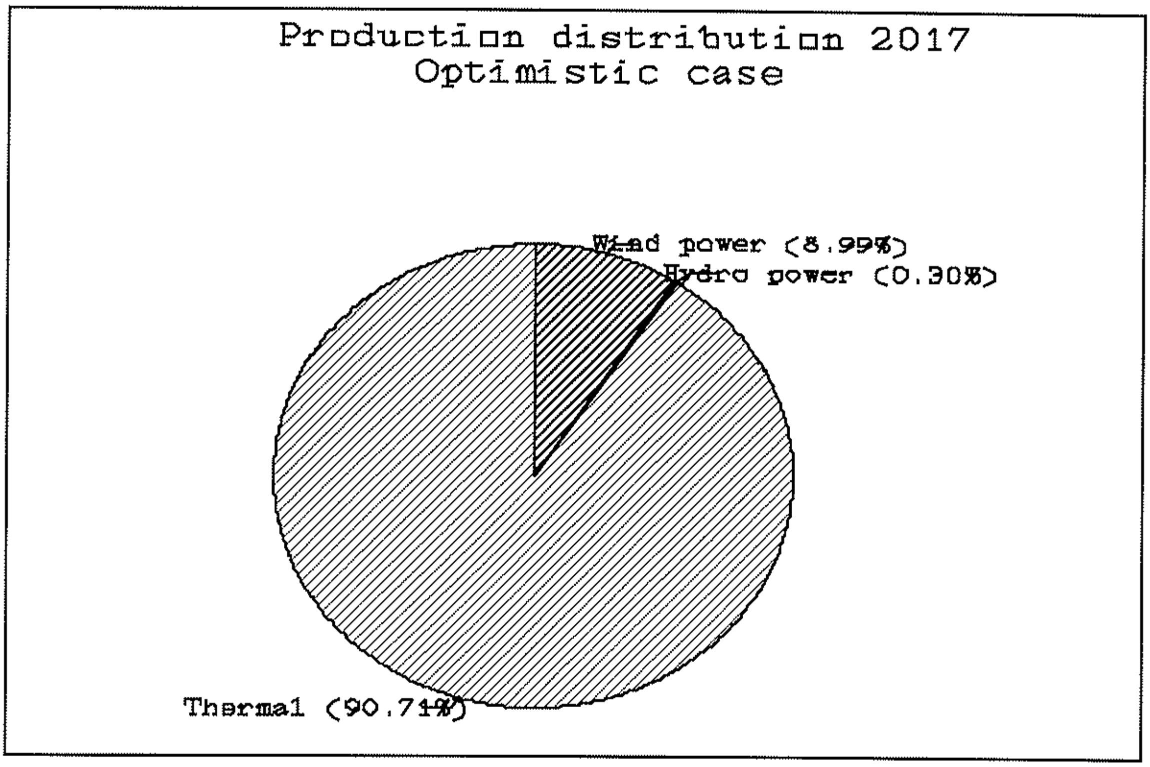

Figure 6 Production by plant categories, Base scenario

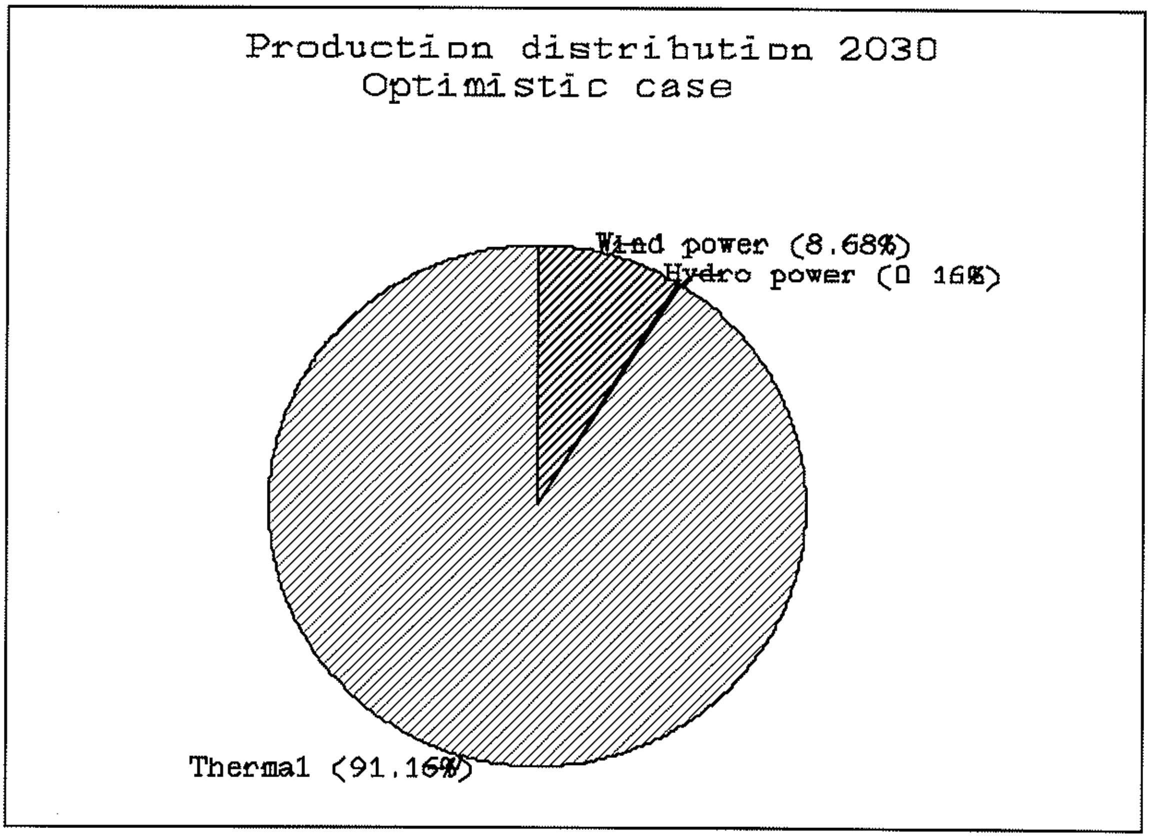

Figure 7 Production by plant categories, Base scenario

In the production system in the Optimistic scenario is outlined with the percentages of each plant category.

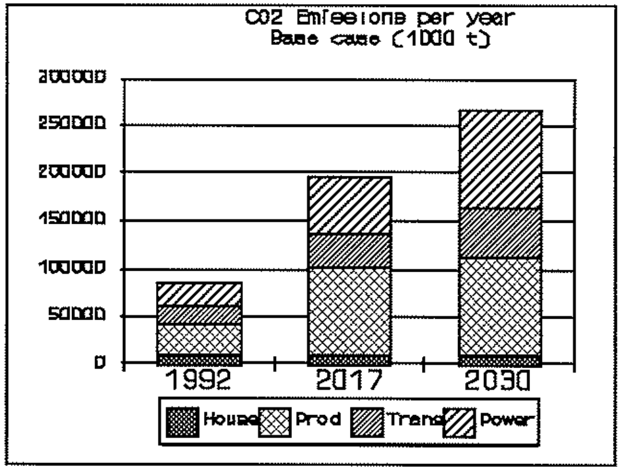

Figure 8 CO2 emissions (Base case)

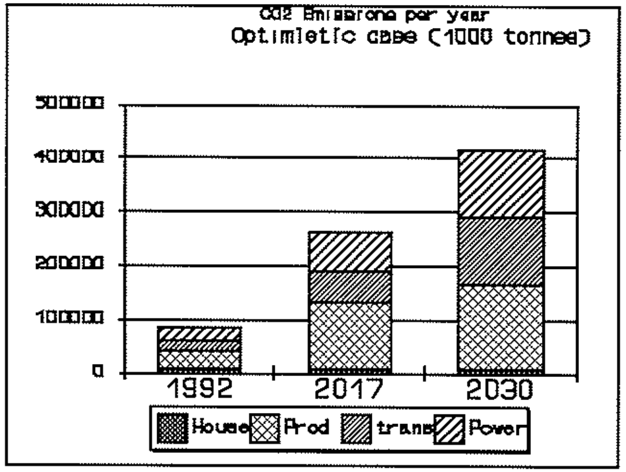

Figure 9 CO2 emissions (Optimistic case)

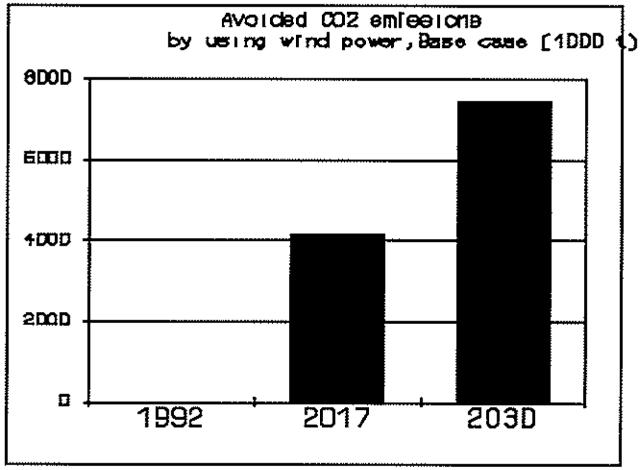

Figure 10 Avoided CO2 emissions (Base case)

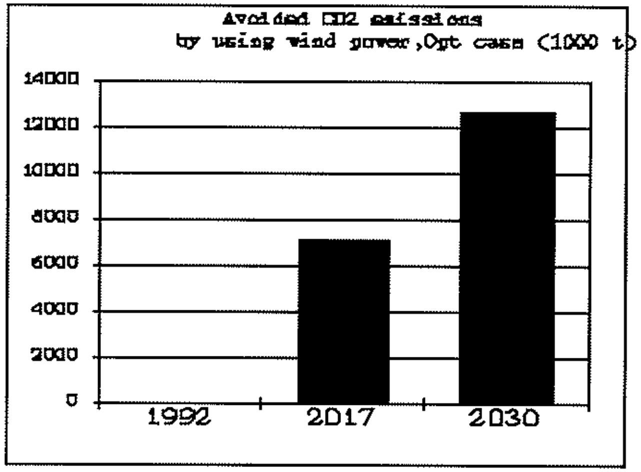

Figure 11 Avoided CO2 emissions (Optimistic case)

In this graph the emission of **carbon dioxide** (CO_2) is illustrated according to the origin: from households, from production, from transport, and from power plants. The large emission in the Optimistic case is caused by the increased GDP. As seen, industry and power plants are the major contributor to the CO2 emission.

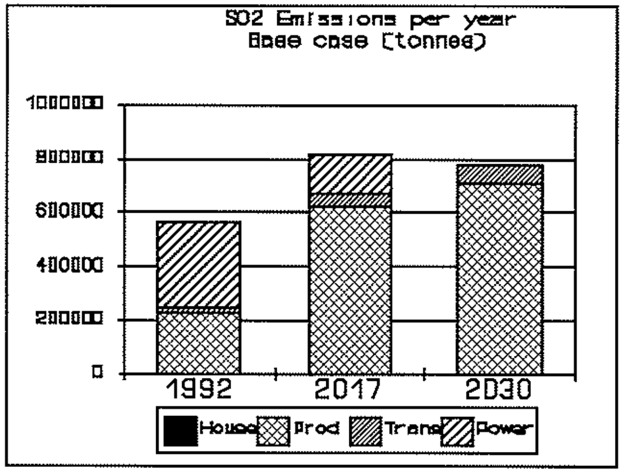

Figure 12 SO2 emissions (Base case)

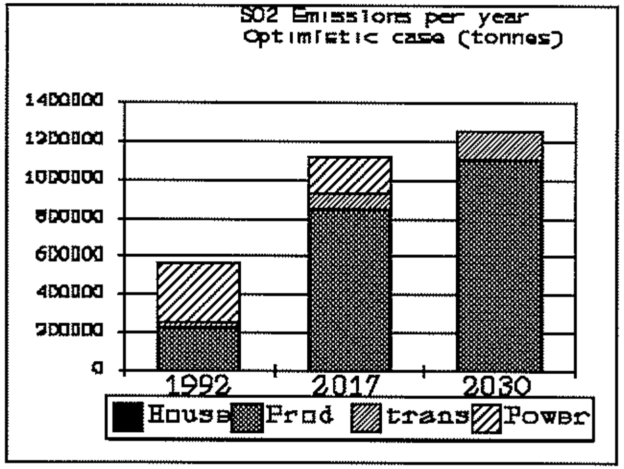

Figure 13 SO2 emissions (Optimistic case)

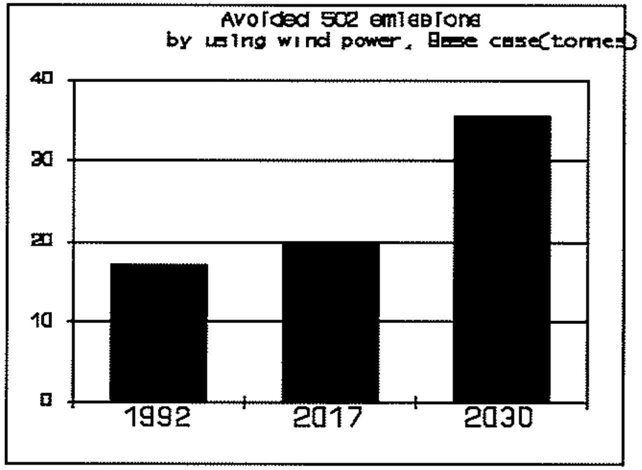

Figure 14 Avoided SO2 emissions (Base case)

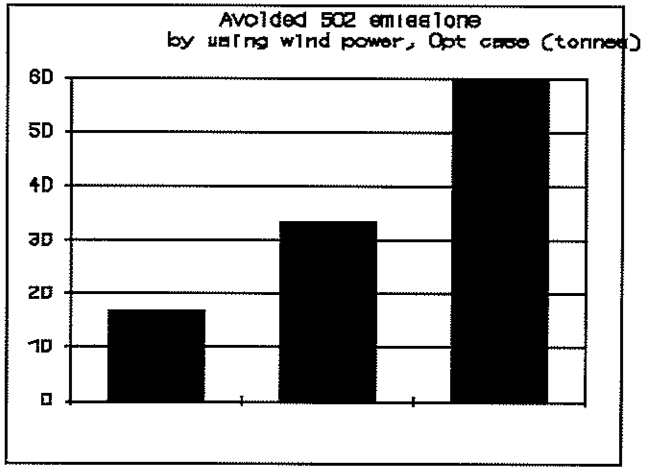

Figure 15 Avoided SO2 emissions (Optimistic case)

In this graph the emission of **sulphur dioxide** (SO_2) is illustrated according to the origin: from households, from production sector, from transport, and from power production. The decreased SO2 from the power plants is caused by the future use of natural gas as fuel. **Note** the units used in the *Avoided SO2 emisions.*

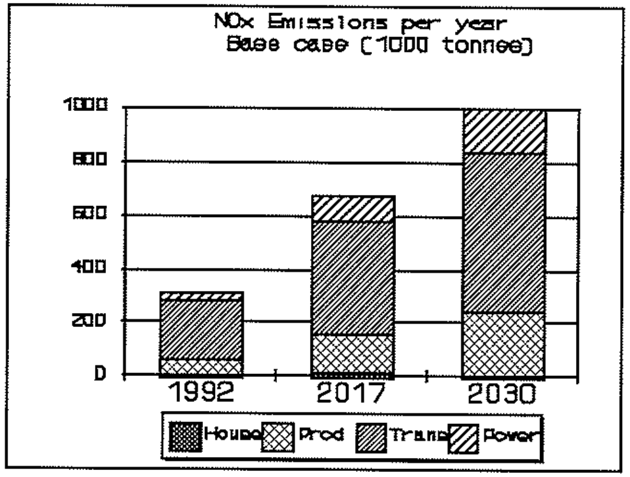

Figure 16 NOx emissions (Base case)

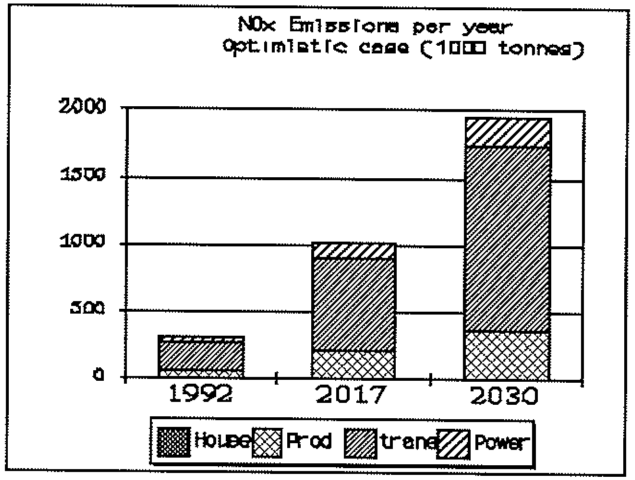

Figure 17 NOx emissions (Optimistic case)

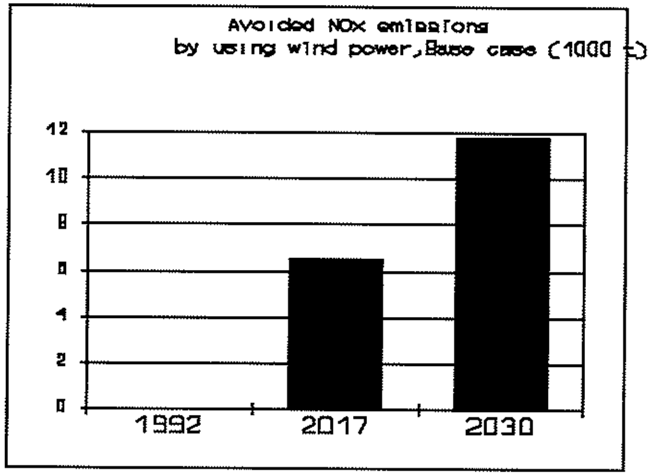

Figure 18 Avoided NOx emissions (Base case)

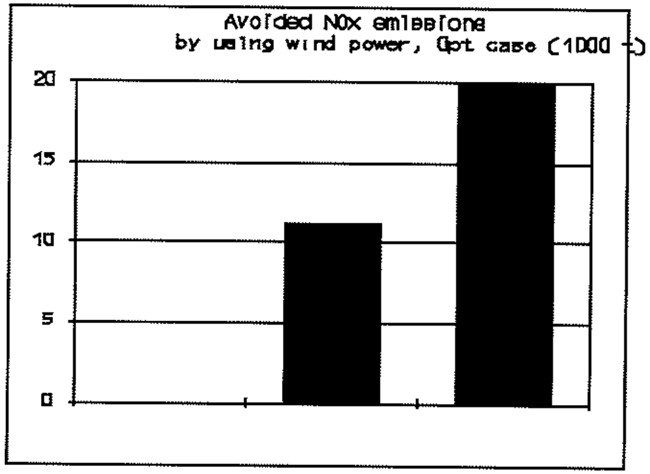

Figure 19 Avoided NOx emissions (Optimistic case)

In this graph the emission of **nitrogen oxides** (NO_x) is illustrated according to the origin: from households, from production sector, from transport, and from power production. The NOx compounds are mostly created during combustion, in boilers, gas turbines, and engines with internal combustion like car engines. The transport sector contributes the major part of the emissions.

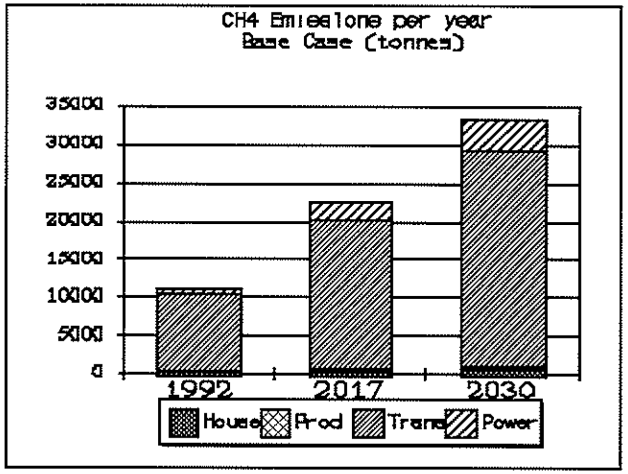

Figure 20 CH4 emissions (Base case)

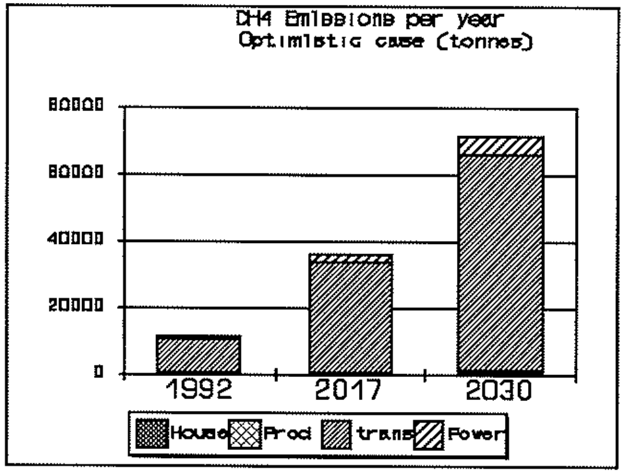

Figure 21 CH4 emissions (Optimistic case)

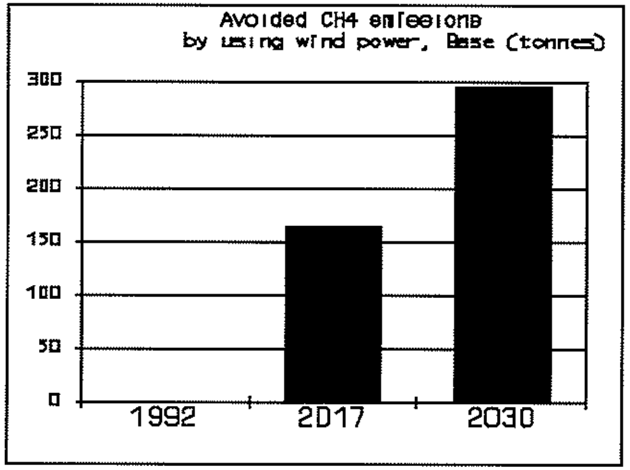

Figure 22 Avoided CH4 emissions (Base case)

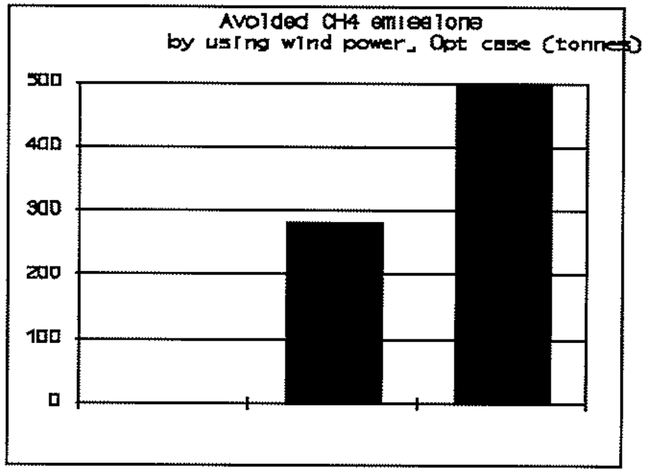

Figure 23 Avoided CH4 emissions (Optimistic case)

In this graph the emission of **methane** (CH_4 - natural gas) is illustrated according to the origin: from households, from production sector, from transport, and from power production. Methane is mostly originating from unburned natural gas and from leaks; bio processes, e.g., in agriculture, contribute, **but are not included in the calculations or in the graph** to the emissions.

7.2.6 Investments in wind farms until 2005

In order to establish of wind farms to the extent that is assumed in the base and optimistic scenarios, economic resources have to be reserved for buying the wind turbines, establish the sites with infrastructure, and erect the turbines. In Table XII, an estimate of yearly numbers for the necessary capital is given for the first few years until 2005. Note, that 500kW turbines are used in this period. As everywhere in this study, the figures are quoted in *fixed* prices. The investments in South Sinai are copied from appendix D.

In the tables, taxes and interests are not included, and there is no distinction between public and private investor. Further, transmission costs in case of wheeling are not considered.

Table XII Selected data until year 2005.

Year	Capacity installed	Investment	Capacity installed	Investment	Capacity installed	Investment
	Zafarana (+)				South Sinai	
	Base scenario		Optimistic scenario			
	MW	Mill. £E	MW	Mill. £E	MW	Mill. £E (*)
1998	30	106	30	106		
1999	50	178	50	178		
2000	60	213	120	426		
2001	60	213	120	426		44.8
2002	100	355	200	710		44.8
2003	100	355	200	710		44.8
2004	100	355	200	710		44.8
2005	100	355	200	710		44.8

Note: (*) 60% import assumed.
(+) Calculated by a specific investment of 3550 £E/kW.

7.3 Sensitivity analysis

A number of quantitative sensitivity analyses has been carried out in order to test the robustness of the assumptions, and to estimate the importance of selected forecasts used in the scenarios; in addition, this section holds some qualitative discussions of the influence of other assumptions.

7.3.1 Parameters examined

The following parameters have been regarded:

Technical and demographic parameters:

1. Wind penetration
2. Average wind speed
3. Population growth
4. For households the following parameters have been varied:
   - The number of electrical appliances
   - The number of persons per household

Economical parameters

1. Fuel prices
2. Electricity prices
3. Wind turbine capacity and cost
4. Life time
5. GDP growth, specified for
   - the agriculture sector
   - the construction sector
   - the industry sector.

The discussion below outlines, where more work is needed regarding these subjects. Other factors may be important, but further analysis has not been carried out in the project.

7.3.2 Results of the analysis

Wind penetration

Changes of the wind capacity have a direct effect on the power generated from the renewable plants and in the total emissions. Since the wind energy is given highest priority, an increased wind capacity implies less power generation from the conventional plants, and therefore less emissions.

In the ES3 simulations the wind penetration has been both halved and doubled from the nominal value, and the results show, that the fluctuating power can be regulated by the power system without operational problems. Further results may be seen in appendix G.

Average wind speeds

The average wind speed at the selected sites is of paramount importance to the economic success of a given project, because the production depends on this quantity. Therefore, every effort has to be done in order to secure reliable measurements in order to improve the accuracy of analyses for selected sites. In appendix E, some studies are reported.

The number of electrical appliances

The number of electrical appliances in households affect directly the electricity demand. The appliances regarded are e.g., cooking facilities, TVs, lighting, washing machines, refrigerators, freezers, air conditions, etc. The numbers are specified as that percentage of the households which has the particular appliance. The electricity consumption in the household sector depends not only on number of electrical appliances, but also on the number of households.

In this connection, it is mentioned, that the number of households depends both on the total population and the number of persons per household. The correlation between the three factors makes a simultaneous change of more than one of the parameters unclear, because, e.g., a small decrease in the population growth rate and a simultaneous decrease in the number of persons per households may cause an increase in the electricity consumption due to the fact, that less persons have been provided with more electrical appliances.

The number of persons per household

The number of persons per households affect the energy demand in the household sector, and has a co-effect on the electricity demand through the number of electrical appliances per household and the population. Please refer to the comments in the paragraph concerning *the number of electrical appliances*.

Through the effect on the energy demand for making heat and hot water, the number of persons per household also affect the emissions from the household sector.

Fuel prices

The energy demand by the process sector depends on the fuel prices; however, the fuel prices have limited influence on the total energy demand. The fuel prices do affect the variable costs of the plants, and thus increased prices will improve the value of renewable power generation compared to conventional production as shown in Table XIII.

Table XIII Conventional production price vs. fuel prices

Fuel Prices [£E/ton]				Production cost [pt/kWh]				
Fuel oil		Nat.gas		Existing[1] plants		New plants		Wind
2017	2030	2017	2030	2017	2030	2017	2030	
Base case, constant prices								
130	130	152	152	9.6	[*]	7.6	8.4	13.5
Base case, 2% increase yearly								
213	276	249	322	12.1	[*]	9.8	12.6	13.5

1 Existing in year 1992
[*] No *Existing* on line

Wind turbine capacity and investment

The capacity of a single wind turbine influences the magnitude of the necessary investment due to the effect of scale: larger unit gives smaller specific investments; this theme has been studied in appendix D.

Life time

The importance of the expected life time of the wind turbines may be illustrated by realizing that a 20 years life time - a typical value and used in this study - means, that in the long term horizon until 2030 all units put on line before 2010 are "out of operation" in year 2030! Thus, 20 years after the first wind turbines have been set up, substitutes for these must be manufactured and installed, in addition to planned new units for expansion of the capacity.

The WTs are presumed to get a major overhaul after ten years operation, and therefore, one could argue, that another major overhaul would extend the active life of the WTs; in future, research and development surely will have made models available with improved characteristics and thus a better economy.

GDP growth in the agriculture, in the construction, and in the industry sector

The industrial GDP growth has a significant effect on the energy consumption in the various sectors (via the elasticity's used in BRUS II). As an example, the yearly GDP growth in the industry was changed from 4% to 5% in the period 2017 - 2030, which resulted in an increase of 7.7% of the energy consumption in this sector. In the Table XIV, the data used for the Base and Optimistic scenarios are given.

Table XIV Yearly GDP growth [% per year]

	Base case		Optimistic case	
	1992-2015	2015-2030	1992-2015	2015-2030
Total GDP growth	3.19	3.07	3.19	3.07
Agriculture	3.30	3.00	4.30	4.30
Construction	4.00	3.70	6.40	5.20
Industry	4.40	4.00	5.50	4.90

8 Constraints

Embarking on a major plan in a rather new field and volume like that outlined in this report will inevitably meet some legal hindrances or technical bottlenecks, which may slow down the realization of the project, or even exclude parts of it; therefore, an important task is to identify constraints and to work out ways to loosen them in order to realize the plan.

The studies carried out so far have found some constraints, that must be observed and dealt with; in the following, they are described in some detail, but it is underlined, that not all possible subjects were studied, and therefore, every thinkable constraint may not have been detected[8].

8.1 Technical constraints

There are two major limitations to carry out the plan as outlined in secs. 6 and 7:

- The industrial capacity
- The industrial capability

Both these factors are important to assess, when Egyptian industry contributes to the production of wind turbines: the rate by which WTs can be finished, ready for installation, depends on the first factor, and the necessary investments on the last factor; in addition, these factors do also influence the electricity production price, the job opportunities as well as the strengthening of the Egyptian industry.

Regarding the capacity, the realization of the proposed plan presumes, that a large number of wind turbines are manufactured each year, ref. Table IV, the exact number depending on the size of the WT, that is selected. The values in the table show, that several wind turbines must be shipped from the factories every week for transportation to the site, and at the same rate, the WTs must be erected, connected, tested, and put into operation on the prepared site.

Appendix C reviews the capability for the Egyptian industry to manufacture wind turbines, totally or partly, and quotes the present capability to be some 30% (in money term) of the WT regarded, a percentage, which is expected to rise the future, depending both on the volume to be manufactured, and the possibilities for transfer of knowledge.

Both factors should be studied in more detail, before a final answer can be given to the question concerning which degree of local manufacture is possible, and thus, its influence on the

[8] The working group, that was supposed to deal with the subjects mentioned in sec. 8.3 never went into action during the project period.

proposed plan.

8.2 Economical constraints

In order to establish the wind farms outlined in this report, some economic factors have to be observed in order to make the project attractive, among which are:

- The necessary investments should be available, whether public or private investor
- The selling price of electricity to the utility should be attractive
- The conditions for wheeling, if relevant, should be known (and attractive)
- Tax rules for private investors should be clear and attractive

In Table XII an estimate of the investments is given, and in appendix D, the selling prices are listed, that should be payed in order to obtain a reasonable Internal Rate of Return (IRR).

8.3 Institutional and legal constraints

In order to establish the wind farms outlined in this report, several aspects of institutional and legal character have to be clarified; some examples are discussed in the following[9], of which some are relevant to all investors, while others mostly to private investors.

In order to attract private investors, a crucial point is the conditions, according to which the wind farms are connected to the public grid, and the utility's obligation to buy the production at a certain price, so this concerns both technical and economic conditions. The technical part may concern e.g., the obligation to supply a specified energy, the quality of electricity, safety aspects, etc. The economic part may relate to the possibility to use the wheeling principle, methods used to fix the selling price, etc. The importance of the latter subject has, as mentioned above, been studied in appendix D, where the dependence of the Internal Rate of Return of a particular project is reported.

Establishment of wind farms involves erection of high structures, 50 - 80 meters, which may interfere with wild life. Trekking birds are using certain "high ways", e.g., along the red Sea cost, and therefore they may hit wind turbines as well as transmission lines while flying during dark hours. Many countries are concerned on these aspects and may preclude certain areas from being used for wind farms. The importance to Egyptian conditions has to be clarified; in appendix C is stated, that "a negligible small effect of the proposed project on fauna and flora as well as on electromagnetic interference and animal life" is expected.

Shortly, the themes like those in the following list should be assessed in detail before deciding upon a project.

- Procedures to establish technical and economic contracts between the wind farm owner and the utility or transmission company
- Conditions for connecting to and transfer electricity through the public grid - wheeling
- Possible permissions necessary to establish and operate wind farms - e.g., due to environmental questions (birds)
- Question of landownership and right-of-way to selected sites

[9] The Working group I, that should have studied these matters, has not been active, and therefore important subjects may not have been identified.

9 Conclusions

The studies carried out by the Working and Model groups under the surveillance of the Co-ordination Group concern a major implementation of wind power in Egypt during the period until year 2030; the principal objective is to exploit the excellent wind resources in various parts of the country, and the results illustrate the benefits for the society in many aspects: economic, resource-wise, environmental, social.

From the studies carried out and reported here, some preliminary conclusions[10] may be drawn concerning benefits and costs both of a continued expansion of the capacity of the wind farm in Zafarana, and of implementation of wind farms in South Sinai. The conclusions will - due to the nature of long term planning - be expressed in broad terms, both regarding the lines which the development may follow, and regarding benefits and costs.

The **general conclusion** is, that within the assumptions underlying the analysis, there seem to be good reasons to continue to develop the utilization of wind energy; the model groups estimated, that below 10% wind penetration, the conventional part of the power system could regulate the stochastic production from wind without problems, and the economic aspects seem to be as good, especially if the industry is encouraged to participate with a high percentage of the manufacture of wind turbines and establishment of wind farms.

The relative short period available for the elaboration of this report together with the underlying studies gave no possibility to go into all details; more work is certainly needed to consolidate both the underlying information and the numerical analysis; also, unsolved questions and problems should be given further examination.

9.1 Selected sites

The analysis confirms, that **Zafarana** is a site with excellent wind resources, situated at the Gulf of Suez's western cost, where the average wind speed is measured to be ~9 m/s, and with ample space available for establishment of large wind farms. This area will be provided with a HV transmission line connected to the national grid and with ample capacity to transfer the foreseen production.

Among the remote sites, which have been studied, without an existing connection to the national grid and where the local power system has rather limited capacity - the following were found to be promising at a first study:

Table XV Selected sites in South Sinai; demands in year 2017

Site	Av. wind speed	Predicted power demand
Ras Sedr	~6.6 m/s	~20 MW
El Tor	~5.7 m/s	~44 MW
Dahab	~6.3 m/s	~19 MW

9.2 Technical aspects

The technical analyses carried out comprised simulations, on an hourly basis, of the power systems including conventional plants as well as wind farms; generally, it was found, that the planned establishment of new wind capacity will not meet any essential constraints; the proposed plan includes

[10] These conclusions relate to the planning studies, whereas the success of the project per se is commented elsewhere.

Table XVI Planned extension of wind capacity in year 2017

Site	Installed capacity		Estimated production		Wind penetration	
	Base	Opt.	Base	Opt.	Base	Opt.
Zafarana	1900 MW	3040 MW	6.5 TWh	11 TWh	6%	8%
Ras Sedr	13 MW		25 GWH		20%	
El Tor	20 MW		25 GWh		15%	
Dahab	14 MW		23 GWH		20%	

capacities and productions as given in Table XVI, that also shows the wind penetration.

However, the implication of specific projects concerning introduction of wind generated electricity into the conventional power systems should be analyzed and checked by other, more detailed models than those used here - but this, of course, is part of the continued planning procedure.

Egyptian industry

The study emphasises, that Egyptian industry may participate in establishment of wind farms by manufacturing parts of the wind turbines, increasing from 30% to day till 60 - 70% - measured in money terms - provided that the necessary technology transfer takes place.

Some points have to be considered:

- the volume of wind turbines to be manufactured and the time schedule as given in sec. 6 and sec. 7
- the sites to be established and the infrastructure to be prepared
- the knowledge to be acquired in order to adapt to the technology, used in modern design of wind turbines

Likewise, the industry may play a significant role in the maintenance of wind farms, including major overhauls and replacement of old units, and the experience obtained in this process makes export of wind turbines possible.

Fuel savings

The production by the wind farms will substitute conventional production, mainly fuelled with oil and gas; in the generating system coupled to the national grid mostly production by older steam units will be replaced, whereas in remote areas, typically diesel production will be substituted. The study estimates, that in year 2017, the total fuel savings in the former system will amount to 6% of a total of 22 mill. t.o.e. in the base case, and 8% of a total of 25 mill. t.o.e in the optimistic case. The remote areas have not been analyzed in this detail.

The fuel, that is saved due to power production by wind, may constitute a potential for export.

9.3 Economic aspects

One important outcome of the study are the costs of electricity, produced by conventional production compared to wind generated at relevant average wind speeds, including investments, operation and maintenance costs; they have been shown to be of the same order, but obviously depending on the expected development of fuel prices.

Typically, the production costs from wind farms are ~13 pt/kWh, whereas conventional production is estimated to 8 pt/kWh assuming fixed fuel costs; an increase of fuel prices like 2% per year results in a conventional produced electricity price of 12.6 pt/kWh in year 2030.

The wind turbines may be imported or certain parts may be manufactured in Egypt; in the latter case, a realistic percentage of local manufacture is 40%, which will decrease the electricity price ~20%, depending on the site and size of WT. Another aspect of local manufacture is the resulting saving of foreign currency.

The wind production will save fuel expenses in the conventional power system and results from the study are shown in Table XVII.

Table XVII Savings of fuel costs due to wind energy (Mill.£E)

Savings due to wind energy	Reference year	Base scenario		Optimistic scenario	
	1992	2017	2030	2017	2030
Wind power	0.1	263.6	475.9	451.0	805.0
Hydro power	415.1	442.4	466.0	442.0	466.0
Total	415.2	705.9	942.0	893.0	1271.0

In order to realize the plans proposed here, investments as given in Table XII are necessary; however, benefits from activity in various parts of the industry will be associated with implementation of the plan.

Wind farm projects may be initiated by private investors on a Build-Own-Operate-Transfer basis; but it may be assumed, that only reasonable profits make them interested. One key factor is the price paid by the utility, and in sec. 6.3, a payment in the range 9 - 15 pt/kWh will secure an Internal Rate of Return of a certain project to be ~15%; this seems to be a realistic price, but the investor will certainly demand a long term agreement in order to judge the investment to be attractive.

9.4 Legal and institutional aspects

This themes were not considered during the project period. Ref. appendix B.

9.5 Constraints

Realization of a major plan as proposed in this report may meet a number of hindrances of technical, economical, legal, and institutional character. The study has identified some, which may be actual during the implementation of certain projects, and thus constitute constraints on their realization; first the assessment of particular projects may disclose all constraints.

Three important items have been identified:

- the capability of the industry to participate in the manufacture, site preparation, erection, and maintenance of the wind farms
- the rules that relate to private investors rights and obligations in any respect like grid connection, wheeling, funding, taxes
- the necessary funding for investments, in the order of 100 - 200 mill.£E per year

9.6 Social consequences

The planning, manufacturing, and operation and maintenance of the great number of wind turbines planned to be established in this study, have significant impact on the society, both in the manufacturing phase of the WTs, and in the site preparation, the operation and maintenance of the wind farms. The number of full time jobs in industry is roughly estimated to 200 per 50 MW wind turbine capacity installed per year, depending on the percentage, that is manufactured locally. In addition, a number of people are needed to operate and maintain the wind farms.

9.7 Environmental consequences

Emission savings

Table XVIII Emissions in the power sector in year 2017

	Emissions due to power production			Avoided emissions	
	1992	Base case	Opt. case	Base case	Opt. case
CO_2 [mill. t]	24.4	60.0	70.7	4.1	7.1
SO_2 [1000 t]	312	145	187	0.02	0.02
NO_x [1000 t]	33	90	106	7	11
CH_4 [1000 t]	0.6	2.1	2.5	0.2	0.3

A direct consequence of substituting conventional power production with wind energy is the decrease of pollution and emission of green house gasses. Due to the shift to natural gas in new power plants, especially the green house gas CO_2, and the pollutant SO_2 are decreased as shown in Table XVIII, that illustrates the consequences.

Wild life

Studies have shown, that at the Red Sea coast, the interaction with wild life is expected to be insignificant. The experience from studies of wild life near wind farms abroad points in the same direction.

10 Recommendations

The **general recommendation** is, that development of wind power plants may follow the plan proposed in this report - under the condition, that the assumptions are valid, and that particular subjects, which are not fully examined here, are devoted further study. This statement is based on the findings of the study, which show that - within the assumptions - further development of utilization of wind energy is possible in selected regions of Egypt; the stochastic production of electricity from wind can be absorbed by the power system; conventional fuel is saved for other purposes; the production costs will be like fossil fuelled production in the future, assuming that the fuel prices are increasing a few percent per year; the Egyptian industry may contribute significantly to the manufacture of turbines and establishment of the wind farms.

Although the consequences of the plan, that is described in sec. 6 and 7 for the coming ~30 years, have been analyzed thoroughly in this report, only those parts which relate to the near future - e.g., covering the duration of the next five-year-plan - have to be considered in detail, because they have a direct and immediate influence on various budgets, other planning, imports, legal and institutional questions, and on industrial production schemes. Therefore, recommendations for the near term are outlined concerning matters relevant to the realization of the plan, and to further studies.

It is underlined, that the main part of this study has been carried out during less than one year - in which also various new aspects of planning technique was trained - and therefore the information, results, and recommendations presented should be regarded as the first step in the continuous planning process, and also, that particular projects and sites require a detailed assessment.

10.1 Selected sites

The study has confirmed - with the available information - that

- **Zafarana** is an excellent choice for establishment of a large wind farm connected to the national grid, with reasonable production costs compared to expected costs from conventional fossil fuelled power plants; the study has shown, that production in year 2017 in the range 12 - 20 TWh (mill. kWh), depending on the scenario, will create no problems in the power system; thus, further expansion of the existing plans seems acceptable and should be considered
- **South Sinai** contains several regions where wind power may be a good option; the study points to the following three remote areas with fair wind conditions and power demand, where it may be beneficial to exploit wind resources in year 2017 like:
  - * **Ras Ghareb**; production ~25 GWh per year
  - * **El Tor**; production ~25 GWh per year
  - * **Dahab**; production ~23 GWh per year

  However, in these areas, only limited knowledge exists concerning local wind distribution and power demand profiles; further measurements are needed in order to improve the calculations

10.2 Wind farm parameters

The analyses have shown, that the following three parameters are important to consider, when the proposed development plan - or part of it - is going to be implemented: wind penetration, size of wind turbines, and aspects of the installation and operation phases.

Wind penetration

The question of the *optimal size of wind penetration* depends on the demand and wind profiles, the structure of the conventional production system, and the production costs; this have to be studied in detail with suitable tools during assessments of particular projects. The present study shows, that wind penetrations up till 20% - 30% do not present significant operational problems like overflow, etc. Therefore, with a development of the wind capacity like that proposed here, having a wind penetration less than 10%, no problems are anticipated in the overall power system. For a particular site or project, however, the grid conditions must be analyzed with regard to local production and demand patterns.

Wind turbines

For a particular site the choice of *size (capacity) and type of wind turbines* depends on several factors:

- Local power demand patterns and existing power system - low loads may require wind turbines stopped
- The turbines reliability - proven and reliable technology may point to "older" types, whereas new designs, although expected to be more efficient, may not be fully matured and therefore not as reliable, as supposed
- Industrial limitations - the maximum size, that can be handled in existing Egyptian factories, may exclude their participation in production of a particular choice of wind turbine
- Economic considerations - benefit of scale, i.e., greater capacity -> cheaper specific investment costs

Installation and operation aspects

It is recommended to assess the following aspects, which are important both at the installation of the turbines at the site, but also regarding the operation and maintenance:

- Constraints, that may be encountered during installation of the turbines, like:
    * at transport: weight considerations, road limits
    * at installation: cranes with sufficient height and weight capacities
- Standardization: Few types and sizes means:
    * Less spare parts
    * Easier training of operation and maintenance crews

The aspects outlined above are not straight forward solved, and they should be assessed further in order to secure a robust strategy for future expansion.

This study has considered turbine sizes in the range 225 - 1000 kW, and for Zafarana recommends 500 kW for the first part of the period and 1 MW later; however, especially in the long run, larger and presumably more efficient WTs will be available, which may change the recommendation concerning the size[11].

Therefore, a recommendation concerning the size of wind turbines depends to a great extend on the site: for **Zafarana**, being planned to have 1800 MW in year 2017, large capacity turbines may be installed, and the industrial limitations will play a significant role, whereas for **remote areas**, the

[11] Presently (1997), Danish manufacturers market wind turbines with capacities around 1.5 MW.

infrastructure and the load pattern may be decisive.

10.3 Financial resources needed

Implementation of the expansion plan requires investments both to set up wind farms and possibly also in industry; the first item is considered here, i.e., only the investments, that are needed to establish the wind farms proper, are considered; that means, that strengthening of transmission lines, substations, etc., are not included; this problem must be assessed for each particular project and site.

The yearly investments have been estimated to 100 - 200 mill.£E in the near term, assuming the Base scenario is followed; for the Optimistic scenario with a higher GDP increase and more wind capacity, the double investment is required. The numbers depend on the percentage of the WTs, that are manufactured in Egypt.

These amounts must be provided by public or private resources, depending on the split between public and private investors.

10.4 Industrial aspects

Industrial companies relevant to the manufacture of wind turbines and establishment of wind farms have been identified, which may contribute to many specific tasks, that are connected with the establishment and operation of wind farms, and inevitably, derived activities will appear:

- Preparation of sites inclusive infra-structure
- Maintenance
- Overhauls
- Replacement of old units at their end of life
- Contracts for foreign services
- Export of hardware and services

In light of the future possibilities to participate in the various tasks, the managements should be encouraged to acquire the necessary capability and capacity to handle the tasks, both by a transfer of knowledge from abroad, and by training of personnel.

10.5 Legal and institutional matters

The rules, laws, and other legal and institutional matters, that have relation to establishment and operation of wind farms, have significant influence on implementation of the proposed plan, and also on the attraction of private investors.

During elaboration of this report little attention was directed towards this subject; therefore, it is recommended, that during the continued work, items like those listed below[12], but not limited to those, are studied in some detail, and if found necessary, steps taken to remedy constraints to a smooth implementation of the plan:

Clarify all aspects for private investors like:

* legal matters regarding investments, tax rules, wheeling
* technical conditions to be observed in order to get connection to the grid like quality, stability, availability, safety, etc.
* economical matters, e.g., price paid for deliverance of electricity, long term contracts

[12] A comprehensive list may be found in appendix A.

10.6 Particular studies

The study of the remote areas in South Sinai was carried out using preliminary data, and a more detailed examination is recommended, when more data are available, as mentioned above.

10.7 Other activities, further studies

The experience gained in this project has shown, that the information collected and compared from participating organisations are important for a consistent and accepted plan for the development of wind energy. Therefore, a continued effort to consolidate the basis for this planning is recommended, in which further consensus may be reached regarding relevant aspects of the plans for development of the Egyptian society; especially those, which are the driving factor for energy demand.

Consequently, continued activity in the organisation established during this project to construct the present plan, is vital for an economic optimal integration of wind energy in the Egyptian power system.

11 Annexes

Discussions during the elaboration of the studies for this report have shown, that the participants have different interpretation of the same subject, e.g., "renewable energy", because of very different background; therefore, a list with explained technical and economical terms and units seems to be useful, and a selection is given below.

11.1 List of units, terms, and definitions

This list is made to clarify certain phrases in the Master Plan report to the reader, who may be accustomed to a certain professional language, but not necessarily to both technical and economical phrases. By means of this list it is hoped, that the text is easier to understand and thus to get correct understanding of the text and tables.

The list is split in two groups: one covers technical matter, while the other relates to economical matter.

Technical matter

Units

Refer to Table XIX below.

Various terms

Availability factor	That part of year, a particular power unit is available, i.e., the time of the year apart from scheduled maintenance and unscheduled stops
Capacity factor	Equivalent number of hours, a particular unit must operate at full power to produce the logged production (at varying power levels); same as Full Load Operating Hours
Full Load Operating Hours	Equivalent number of hours, a given unit must operate at rated power to attain the logged production
Demand factor	Equivalent number of hours, a unit with capacity = peak demand should operate to produce the yearly demand
Emission factor	Amount of a given chemical compound emitted per unit of a particular fuel, burned at specified conditions
Efficiency	Fraction of the energy contained in the fuel, that is transformed to useful energy
Excess production	That part of the production of a wind turbine, for which there is no demand
Priority list	That ranking, in which the available units are ordered and put into operation (production), according to particular conditions; used in simulation of the power system
Remote areas	Communities provided with electrical grid without connection to the national grid
Wheeling	Transmission of energy from a particular wind farm through the (national) grid to a given consumer, usually the owner of the wind farm
Renewable sources	Sources of energy, that are replenished by nature itself, e.g., by

the sun; in the power system, hydro and wind are renewable but note, that pumped storage plants, although using water as working fluid, are *not* renewable sources, because electricity is used to pump the water to the reservoir

Definitions (mathematical expressions)

Energy produced = Peak load * Load factor

or - which is equivalent

Energy produced = Peak load * Full Load Operation Hours

Reserve capacity = 100 - 100 * Peak Demand / Installed capacity (%)

Economical matter

Units

£E	Egyptian pounds are used throughout in order not to include an unknown or estimated future exchange rate

Terms

GDP	Gross Domestic Product
NPV	Net Present Value
IRR	Internal Rate of Return
Elasticity	The effects on a particular variable due to changes of another
Sector	The energy relevant parts - sectors - of the society is grouped according to demand characteristics
Real prices	Prices without inflation
Running price	Prices including inflation

Table XIX Energy and power units

Numeric equivalents

Abbreviation	Name	Value (numeric)	Value (name)
k	kilo	10^3	thousand
M	mega	10^6	million
G	giga	10^9	billion
T	tera	10^{12}	trillion
P	peta	10^{15}	quadrillion

Abbreviations

kWh		10^3 Wh	kilowatt hour
MWh		10^3 kWh	megawatt hour
GWh		10^6 kWh	gigawatt hour
kJ			kilo joule
MJ		10^3 kJ	mega joule
GJ		10^6 kJ	giga joule
TJ		10^9 kJ	tera joule
PJ		10^{12} kJ	peta joule

Electrical Power & Energy

1 W	= 1 J/s		
1 kWh	= 3.6 MJ		

Energy conversions used

1 t.o.e.	= 41.9 GJ	= 11.6 MWh	ton oil equivalent

11.2 Emission factors

Table XX Emission factors [kg/GJ fuel]

	CO2	SO2	NOx	N2O	CH4
Power sector					
Steam units					
- old	77.4	1.24	0.1	0.002	0.0015
- new	63.1	0.0	0.1	0.001	0.0025
Combined cycle					
- old	63.1	0.0	0.1	0.001	0.0025
- new	63.1	0.0	0.1	0.001	0.0025
Gas turbines					
- old	63.1	0.0	0.1	0.001	0.0025
- new	63.1	0.0	0.1	0.001	0.0025
Transport sector					
Diesel oil	74	0.0023	0.984	0.051	0.0072
Fuel oil	77	1.485	1.411	0.003	0.0083
Gasoline	69	0.005	0.859	0.022	0.0974
Jet petroleum	71	0.005	0.204	0.000	0.0114
Other oil prod.	73	1.163	0.150	0.003	0.0001
Industrial sector					
Gas oil	74	0.005	0.10	0.03	0.0001
Fuel oil	77	1.163	0.15	0.03	0.0001
Natural gas	63	0.0003	0.10	0.02	0.0003
Coal	95	0.714	0.20	0.02	0.0003

The emission factors given in Table XIX depend on the fuel and combustion technology specified.

12 References

12.1 Third Five-Year Plan for Socio-economic Development in Egypt, vol. I, April 1992.

12.2 Strategy to use Petro-chemical products an natural gas till 2020, Organization for Energy Planning and Conservation OECP, 1955.

12.3 UNEP Greenhouse Gas Abatement Costing Studies, Case study on Egypt, EEAA, 1955.

12.4 Central Board of Egypt, Annual Report, 1994/95.

12.5 Egyptian General Petrokem Corporation (EGPC), Annual report, various issues.

12.6 Egyptian Electricity Authority (EEA), Annual report, various issues.

12.7 Estimating the price and income elasticities by energy type in Egypt, OECP, 1996.

12.8 Various data from EGCP, EEA, CAPMAS, Ministry of Planning, EEAA, and OECP.

12.9 Agendas/Minutes from meetings in Co-ordination group and Working groups

12.10 Reports from the Working groups

12.11 BRUS II analyses / reports

12.12 Report on Expected & Optimistic Scenarios for years 1992, 2017, 2030 [ES3 analyses], October 1996

12.13 BRUS II. Input data and relations, P.S.Christensen and K.Skytte, Risø National Laboratory, RISØ-I-1076(EN), 1996

12.14 ES3 manual

12.15 *Project proposal*:

Demonstration and development of technology and planning in the wind sector in the Arab Republic of Egypt, Risø National Laboratory, Roskilde, and Ministry of Foreign Affairs, Copenhagen, April 1992

12.16 Mission reports

Appendix A Organization, responsibilities, tasks

The following contains a description of the organization that contributed to the elaboration and realization of the Master Plan report; the organization was formulated during the first phase of the project, and the members were appointed of the affected authorities and initiated the planning of the tasks to be carried out. In the second phase, the Co-ordination and Working groups carried on with elaboration of the details of the Master Plan report, supported by Risø. Along with these activities, the model groups, which are dealt with in appendix F and G, analyzed the consequences of specified assumptions concerning possible establishment of future utilization of wind energy by establishment of wind farms.

A.1 Objectives

From the proposal the following objectives are copied:

"The overall objective of the second phase of the Master Plan Component project is to establish a process for co-ordinated planning of future options for utilisation of wind energy. The objectives - as they appear in the contract - are still valid, and the fact that wind energy now is part of the energy planning by EEA and the national planning, underlines the need for continuing the effort to strengthen the capabilities of NREA.

"The importance of the master plan is seen from the fact, that in the running five-year-plan budgets for utilisation of renewable sources are allocated, which can be drawn upon for specific projects, that are assessed positively.

"To support the preparatory work of the five-year-plan (1997-2002) for Egypt a preliminary master plan report is presumed, which includes various scenarios for future utilisation of wind energy.

"Consequently, the Master Plan report shall outline a strategy for the development of the wind energy sector, and point out important measures to support this development. Experiences gained in the wind energy sector during recent years form a basis for the planning and the strategy to be pointed out in the Master Plan.

"The establishment of the Technology Center at Hurghada and the planned wind farm at Zafarana are such important bases for the experience and the future role of the Center in developing the use of wind energy is to be a specific task for the Master Plan. Zafarana should serve as an example to assess the optimal magnitude of large scale wind farms. Also the future role of the Center may be an important issue concerning testing and approving new design of Egyptian and foreign WTs.

"It is also the intention to point out areas for further development of wind energy - sites, technologies, etc. Along with information on electricity demand, the grid capacity, need for pumping, and the sites available, a visualization of the possible development in wind energy is made.

"Finally, it is remarked, that the contents of the master plan report will be based on information available until January 1997. At that moment, the wind farm at Zafarana has not provided much information, which would have been very important for the master plan work. Logically, the planning has to be considered a continuous process, in which this project is the first step.

"Development objectives

" To provide a framework in which the wind energy planning will be considered in the national planning

" To provide a strengthening of the Egyptian capability in the field of energy planning

" To establish capabilities to utilize wind power to a much greater extend as a supply of energy

"Immediate objectives

- "The preparation of reports by the WGs
- "The preparation of a preliminary master plan report
- "The planning and running of a seminar where the preliminary report is presented, and where the participants - specialists in related fields - will comment the report
- "The preparation of the final master plan report, taking into account comments given at the seminar
- "Dissemination of results

In order to carry out the study in an optimal manner the various tasks of the project have been delegated to four Working Groups, each with a specified objective, and consequently, with a selection of members who are experts in the particular field and belonging to an institution which plays a major role in the field. Below the set-up is copied from the proposal:

"Thus, one of the main objectives of the project is to ascertain that information useful as a contribution to the national five-year plan is obtained. That is, to make a report containing a plan which describes the assumptions, actions, and means along with the expected benefits for the Egyptian society - all necessary to attain the goals put forward in national plans.

"The objectives, responsibilities, and therefore the actions, have been distributed among a co-ordination and four working groups. The Co-ordination Group (CG) has the overall view of all responsibilities and corresponding activities, whereas the Working Groups (WGs) are more specialized. In broad terms the objectives are as follows:

- "assessment of possibilities to reach the goals in the national plans through studies of selected scenarios
- "identification of possible barriers to reach the goals
- "formulation of legal procedures and rules necessary to implement the plan
- "selection of methods to establish the plan
- "assessment of consequences of implementation of the plan in all aspects, including environment and externalities

"In the following the organization, obligations, and activities in the CG and the WGs are described. It is evident, that it is not possible - inside phase II - to study every aspect listed below in details, but all should be addressed in the continuous planning process.

"In general, the working groups should prepare data for the Master Plan, including those necessary for scenario runs, and later, the WGs should study and comment the results and consequences before preparing reports to the CG.

"As mentioned in sec. 3, it is regarded valuable to take into account any knowledge - and advice - which pertain to the impact of establishment of wind parks on the environment. This suggests inviting EEAA - the Egyptian Environment Affairs Agency - to join relevant working groups. The result should be to take appropriate measures or establish appropriate planning procedures concerning sites which are critical in respect to e.g. migrating birds, when sites are selected for future wind parks.

"During Phase I the transference of the methods and models were of high priority. During Phase II Risø's support is aimed at further model adaptation to Egyptian needs, training to use the models, as well as at supporting the work in the CG and the WGs, setting up the details of the master plan.

A.2 Organization

From the proposal, the following paragraphs are copied concerning the organization that was established during the first phase of the project. This organization was supposed to carry out all analysis and reporting leading to a master plan report.

A.2.1 The Co-ordination Group

The objectives of the CG are:

The CG will be responsible for the overall co-ordination of the WGs' activities to fulfil the objectives of the Wind Energy Master Plan in view of the national energy policies and priorities. The CG will also follow up and update the master plan.

Presently, the CG consists of 11 persons + the chairman. It was formed according to the decree of the Minister of Electricity and Energy, stating the responsibilities of the committee. The members represent the following organizations and authorities:

1. New and Renewable Energy Authority (NREA)
2. Egyptian Electricity Authority (EEA)
3. Ministry of Industry
4. Ministry of International Co-operation
5. Ministry of Planning
6. Organization for Energy Conservation & Planning (OECP)
7. Ministry of Agriculture and Land Reclamation
8. Local manufacturers
9. Meteorological Survey Authority
10. Localities
11. Rural Electric Authority (REA)

The responsibilities and activities of the CG are:

- Co-ordinate the activities of the WGs and to ensure integration and consistency between them.
- Follow the Development and updating of Wind Energy Master Plan report within the framework of the National Energy Plan.
- Review and approve the WGs' recommendations and work plan on regular basis.

- Disseminate the objectives, plans, and achievement of the wind energy programs to the concerned bodies, particular local planning and financial authorities to ensure its integration within national industrial energy and development plans
- Take necessary measures and develop required regulation and legislation for the promotion of wind energy use
- Evaluate scenarios and emphasize priorities that fit into the energy plan.
- Review and approve wind energy projects and plans in the framework of the master plan
- Co-ordinate plans, programs and financial resources with local authorities and donor agencies (e.g. DANIDA, USAID, Dutch, and German donors), as well as private investors.
- To nominate participants in the technical missions to Denmark

An important activity of the CG is to define the general roles of EEA which has the necessary data on the supply, demand, and existing planning of the power system, and of OECP which has a general expertise in demand forecasts, GDP, energy pricing, etc., and will analyze the results and describe the influence on other sectors. Therefore, EEA and OECP should take an active role in the planning procedures.

A.3 The working groups

Presently, four working groups take care of certain areas of the information necessary to establish the master plan.

A.3.1 Working group I - Institutional Responsibilities

The objectives of this group are:

To identify packages of obligations and responsibilities required to fulfil the master plan realization. To identify appropriate organizations to be committed to each package and the interface mechanisms between the different organizations.

This working group was formed as the other WGs according to the decision of the CG. Its members represent the following organizations:

1. NREA
2. Red Sea Governorate
3. Matrouh Governorate
4. North Sinai Governorate
5. South Sinai Governorate
6. Cairo Electric Energy Distribution Company
7. Rural Electric Authority
8. Arab Industrialization Authority (AIA)

The responsibilities and activities of this group are:

- Review implementation requirement of the wind Master Plan.
- Identify packages of obligations and concerns to be considered including identification of the required capabilities and mandates for their realization. This may include but is not limited to matter related to:
  - Siting
  - Ownership of land and machines
  - Project development and engineering

    - Manufacturing and supply
    - Contracting
    - Project management, implementation, and follow-up
    - Construction and start-up
    - Connection to the grid
    - Operation and maintenance
- Identify possible interface mechanisms between the different organizations and follow up upon the implementation of obligations
- Reporting to the CG

A.3.2 Working group II - Wind Industry and Marketing

The objectives of this group are:

Initiation, follow up, and realization of working plans for development of local wind industry. Such plans should concur with the wind technology development world wide and the market in Egypt and the Middle East, as appropriate. Further, evaluation of the feasibility of wind turbine production, wind energy utilization, and exports - grid connected and non-grid connected systems - and, finally, identification mechanisms for their implementation.

The members of this working group represent the following organizations:

1. NREA
2. Arab Industrialization Authority (AIA)
3. Suez Canal Authority

The responsibilities and activities of this group are:

- Review existing local industrial capabilities to manufacture wind system components as related to most current development of the technology. Such reviews have to be updated biannually.
- Identify appropriate in-country capabilities for various components and make plans for their integration in order to realize the required manufacturing objectives including further design development
- Identify and evaluate possible technology transfer options and recommend plans for their development
- Review market assessments and develop scenarios for their satisfaction. This will include definition of production capacities, type of production, priorities for implementation
- Assess the needs for development of financial and investment requirements for the wind industry
- Identify needs for and/or initiate feasibility studies of industrial capabilities
- Evaluation of possible utilization of wind energy to satisfy energy needs, and forecast the required capacities and system requirements
- Assess updated information about electrical grid characteristics, needs, and development plans
- Reporting to the CG

A.3.3 Working group III - Investment and Finance

The objectives of this group are:

To evaluate required investments for the realization of the wind energy programs and master plan, as well as to investigate means of securing - and follow up upon - possible financial resources for the realization of the master plans.

Its members represent the following organizations:

1. NREA
2. Investment National Bank
3. Ministry of Planning
4. Ministry of International Co-operation

The responsibilities and activities of this group are:

- Assessment of the required investments and budgets for the realization of the wind energy programs and plans
- Investigation of possible financial resources and follow up upon their utilization
- Co-ordination with financial authorities, donor agencies, and users
- Review and follow up of financial contracts and plans; advises on bottlenecks to overcome
- Participation in preparation of the financial aspects of feasibility studies
- Reporting to the CG

A.3.4 Working group IV - Siting and Application

The objectives of this group are:

To assess the availability of appropriate sites for wind systems installation. This will involve both resource reviews, needs identification, and land requirement determination. Further, to review assessments of potential wind energy application - grid connected and non-grid connected.

The members of the group represent the following organizations:

1. NREA
2. Meteorological Survey Authority
3. Egyptian Electricity Authority
4. North Sinai Governorate
5. South Sinai Governorate
6. Rural Electrification Authority
7. Organization for Energy Conservation & Energy (OECP)

The responsibilities and activities of this group are:

- Assessment of wind energy availability in various potential locations for its utilization
- Identification of candidate areas for wind energy projects
- Consideration of all administrative, legal, and institutional procedures and approvals regarding land ownership, safety, electromagnetic interference, infrastructure, physical planning, environmental assessment, e.g. concerning

    - impact on birds
    - visual impact

- noise

- To review available wind data for candidate sites, and to identify further need for wind resource assessment:

  - Investigation of wind energy potentials in promising areas based on data from NREA and others
  - Preparation of plans for evaluation of wind energy availability in different locations
  - Identification of the most appropriate and justified locations for wind energy systems

- To identify potential sites for wind projects and evaluate their appropriateness for application, and their required infrastructure:
  - Identification and selection of candidate sites and areas required for wind farm projects
  - Consideration of institutional procedures, approval of land ownership and access to services, road, telephone lines, etc.
  - Recommendation of appropriate sites in the areas concerned according to access to services, roads, transmission grid, etc.

- Assessment of application options for wind energy systems at location with promising wind resources through different scenarios
- Recommendation of priorities and identification of needs for pre-feasibility studies
- Preparation of reports for other WGs for their evaluation of needs to achieve the forecasts
- Recommendation of mechanisms for realization of wind energy projects
- Reporting to the CG

The tasks and activities, that follow from the text above, are described in the following appendices. The results from these are integrated into the Master Plan report, where applicable. For details, reports by the Co-ordination and Working groups and to Minutes of Meetings - available at NREA - may also provide information concerning the elapse of the process of elaborating the Master Plan report.

Appendix B Contribution from WG I, Institutional responsibilities

In this appendix contributions and reports from the Working Group for Institutional Responsibilities, WG I, are compiled along with a short review.

B.1. Tasks

According to the organization of the project, the tasks of this group are:

* To identify packages of obligations and responsibilities required to fulfil the master plan realization. To identify appropriate organizations to be committed to each package and the interface mechanisms between the different organizations.

* Responsibilities and activities of this group are:

1. Review implementation requirement of the wind Master Plan.
2. Identify packages of obligations and concerns to be considered including identification of the required capabilities and mandates for their realization. This may include but is not limited to matter related to:
3. Siting
4. Ownership of land and machines
5. Project development and engineering
6. Manufacturing and supply
7. Contracting
8. Project management, implementation, and follow-up
9. Construction and start-up
10. Connection to the grid
11. Operation and maintenance
12. Identify possible interface mechanisms between the different organizations and follow up upon the implementation of obligations
13. Reporting to the CG

B.2. Activities

The activities of this WG will - as seen above - concentrate on requirements and obligations important to implement those projects, that were identified during the preparation of the master plan report. However, no activity in this Working Group has been recorded.

B.3. References

None

Appendix C Contribution from WG II, Industry & Marketing

In this appendix Contributions and Reports from the Working Group for Wind Industry and Marketing, WG II, are compiled along with a short review of the final report.

C.1. Tasks

According to the organization of the project, the tasks of this working group are:

* Initiation, follow up, and realization of working plans for development of local wind industry. Such plans should compete with the wind technology development world wide and the market in Egypt and the Middle East, as appropriate. Further, evaluation of the feasibility of wind turbine production, wind energy utilization, and exports - grid connected and non-grid connected systems - and, finally, identification mechanisms for their implementation.

* Responsibilities and activities of this group are:

1. Review existing local industrial capabilities to manufacture wind system components as related to most current development of the technology. Such reviews have to be updated biannually.
2. Identify appropriate in-country capabilities for various components and make plans for their integration in order to realize the required manufacturing objectives including further design development
3. Identify and evaluate possible technology transfer options and recommend plans for their development
4. Review market assessments and develop scenarios for their satisfaction. This will include definition of production capacities, type of production, priorities for implementation
5. Assess the needs for development of financial and investment requirements for the wind industry
6. Identify needs for and/or initiate feasibility studies of industrial capabilities
7. Evaluate possible utilization of wind energy to satisfy energy needs, and forecast the required capacities and system requirements
8. Assess updated information about electrical grid characteristics, needs, and development plans
9. Report to the CG

C.2. Final report by the Working Group

The report gives a review of that part of the Egyptian industry which may contribute to realization of projects, identified during the preparation of the Master Plan report, the following aspects were studied:

* Manufacturing of wind turbine components
* Erection of wind turbines
* Technical support and maintenance

The Egyptian industry has experience from the manufacture of 100kW and 300kW machines, where tower, main frame of nacelle, and blades were manufactured, partly utilizing technology transfer.

The report points out the following companies as candidates for new production:

* Egyptian Iron & Steel Company, EISCO
* ElNasr Casting Company
* Helwan Machine Tool Company
* Suez Shipyard, SSHY, Suez Canal Authority
* The Egyptian Company for Metallic Construction, METALCO
* Banha Company for Electric Industries, MF144
* Aircraft Company
* Aircraft Engine Company
* El-Nasr Steel Pipes & Fitting Company
* Shoubra Company for Engineering Industries, MF27
* Industries Engineering Company, ICON
* El-Hawamdia Sugar Company

It is not foreseen in the report, that all parts may be produced domestically; presently, some more specialized items will be imported. Components mentioned in the following list can be manufactured in Egypt:

* Tower
* Main frame of nacelle and its cover
* Main shaft, partly
* Hub, partly
* Blades
* Electric power components like cables, transformers, lattice towers and conductors for transmission lines

In any case, the following parts are foreseen to be imported:

* Yaw components like gear, bearing, and motor
* Housing and bearings for main shaft
* Gear box and bearing for gear box
* Electrical generators
* Braking systems
* Control systems & computers (may be assembled in Egypt)

The report expects, that the percentage (in money terms) will increase during time due to adaption of new technology, to establishment of new factories, and to transfer of knowledge - and expects the percentage to rise from 30% at present to the range 60 - 70%, depending on the actual circumstances, e.g., the number of wind turbines planned to be installed.

The report also estimates the social impacts in Egypt of introducing wind power, based on both partial local manufacture of the wind turbines, the installation, and the operation & maintenance of the wind farms. For the manufacture, some 8 man-years of labour are needed for a 200kW WT.

A case study is included concerning South Sinai, where three localities are analyzed: Ras-Seder, El-Tor, and Dahab, each planned to have 10 - 20 MW wind farms in year 2017, corresponding to 20 - 40 500kW units. This is estimated to create some 4000 job opportunities, the necessary local support not taken into account.

C.3. References

Report on Local Manufacture of Wind turbine in Egypt, by eng. Salah Abdel-Hafiez, NREA, March 1997; 14 pages.

Appendix D Contribution from WG III, Investment & Finance

In this appendix contributions and reports from the Working Group for Investment and Finance, WG III, are compiled along with a short review.

D.1 Tasks

According to the organization of the project, the tasks of this working group are:

* To evaluate required investments for the realization of the wind energy programs and master plan, as well as to investigate, means of securing, and follow up upon the possible financial resources for the realization of the master plans.

* Responsibilities and activities of this group are:

  1. Assess the required investments and budgets for the realization of the wind energy programs and plans
  2. Investigate possible financial resources and follow up upon their utilization
  3. Co-ordinate financial authorities, donor agencies, and users
  4. Review and follow up on financial contracts and plans; advise on bottlenecks to overcome
  5. Participate in preparation of the financial aspects of feasibility studies
  6. Report to the CG

D.2 Final report by the Working Group

The report considers the economic aspects of establishment of wind farms at Zafarana and in South Sinai, using wind turbines either fully imported or with certain components manufactured in Egypt.

The analysis concentrates on

- levelised production cost
- selling price at given internal rates of return
- required investments
- necessary financial resources

and the conditions for public as well as private investors are studied.

D.2.1 Levelized production cost of wind energy

The report contains an assessment of the installation and running costs of a wind turbine erected in a wind park, both for a 100% imported machine and for one, where 40% of the components are manufactured in Egypt. As an example, the table below shows the costs split on various items for a 225 kW machine:

Cost item	Part of investment	Fully imported	40% local
Investments	%	1000 £E	1000 £E
Wind turbine FOB		816.0	718.1
Customs	16	130.6	78.3
Insurance	2	16.3	9.8
Price CIF		962.9	806.2
Transport & installation	5%	48.1	40.3
Foundation & civil works	7	67.4	56.4
Cables & Elec. works	7	67.4	56.4
Spare parts	2.5	24.1	20.2
Total per WT (1)		1169.9	979.5
Running costs		1000 £E/year	1000 £E/year
Operation & Maintenance	5	58.5	49
Overhauls (2)	15	175.5	146.9

Notes: (1) in a wind park
(2) after 10 years

Usually, the exact value of many items are unknown, and therefore the percentages seen in the table are standard values.

From the numbers above, the levelized price are calculated using a life time of 20 years for the single WT, and a rate of return of 4.5%. A cash flow calculation gave the results in the table below, referring to four locations with different wind speeds:

Size of WT	Location				
	Zafarana	East Ow.	Dahab	Ras Sedr	El Tor
220kW		45	18	20	14
100% import	12.9	30.0	32.5	29.0	40.0
60% import	11.3	25.8	27.0	24.5	34.0
300kW		1050	473	526	368
100% import	12.6	26.4	27.9	25.2	35.9
60% import	10.5	22.4	23.4	21.1	30.1
500kW		1800	832	920	622
100% import	11.8	24.4	25.6	23.0	34.0
60% import	9.9	20.4	21.0	19.0	29.0
Capacity fac.	45	20	18	20	14
Energy (MWh/y), 220kW	760	332	315	350	250
300kW	1050	500	473	526	368
500kW	1800	875	832	920	622

D.2.2 Selling price of wind energy

The selling price of electricity - produced by a wind turbine - has been calculated both for public and for private investors by a cash flow analysis. The cash flow has been estimated taking the following components into account:

- expenses necessary to operate the wind farms:
  * investments
  * operation & maintenance costs
- income or savings:
  for private investors:
  * sale of electricity
  for public investors (savings in the conventional power system):
  * capacity savings
  * fuel savings
  * O&M savings

In order to attract investors, a particular project should have a positive net-income, e.g., as characterized by the Internal Rate of Return; in the table below those selling prices, which give a certain IRR are listed for various sizes of WTs and sites, both for private and public investors.

Selling prices	Unit	Public, IRR = 13.5%		Private, IRR = 15%	
Size of WT		Zafarana	Dahab	Zafarana	Dahab
220kW 100% imp	pt/kWh	13.0	36.5	15.0	38.0
60% imp	pt/kWh	10.0	29.5	13.0	31.0
300kW 100% imp	pt/kWh	12.2	31.0	14.5	33.0
60% imp	pt/kWh	9.5	25.0	12.0	27.0
500kW 100% imp	pt/kWh	11.2	27.8	13.8	30.0
60% import	pt/kWh	8.7	22.4	11.2	25.0

D.2.3 Assessment of the required investments

In order to establish the capacity of wind parks studied in this report, the following tables give the yearly capital, necessary for the particular sites. All numbers refer to 500kW machines, stated in fixed prices (no inflation).

Year	Zafarana		Dahab (1)		Ras Sedr (1)		El Tor (1)	
Import	100%	60%	100%	60%	100%	60%	100%	60%
2000	292	245						
2001	292	245						
2002	487	408	14.6	12.2	5.0	4.0	34.0	28.6
2003	487	408	14.6	12.2	5.0	4.0	34.0	28.6
2004	487	408	14.6	12.2	5.0	4.0	34.0	28.6
2005	487	408	14.6	12.2	5.0	4.0	34.0	28.6

(1) *Assumed to be established in year 2002.*

D.2.4 Possible financial resources

The report emphasizes the importance of activating the private sector, e.g., by the BOOT concept: Build, Own, Operate, and Transfer; hitherto NREA had the responsibility of establishment of wind farms.

The National Bank will finance projects included in governmental plans and approved by the Ministry of Planning; during realization of the project, the bank will follow the implementation.

Donor organizations are also considered valuable sources for financing wind projects, and aside from Danida, UNDP, KFW, and USAID may contribute.

D.2.5 Conclusions

The Working Group for Investment & Finance draws the following conclusions of their study:

- The capacity of the WT has a marked effect on the levelised production cost, as an increase from 225kW to 500kW will reduce the LPC by 1.1 pt/kWh in Zafarana, and by 0.9 pt/kWh in South Sinai

- Likewise, local manufacture of certain components of the WT amounting to 40% of the investment for a single WT will reduce the LPC by 1.9 - 2.1 pt/kWh in Zafarana, and by 4.5 - 6.0 pt/kWh in South Sinai
- The wind regime - characterized e.g. by the annual mean wind speed - has a marked influence on the production and economics, and is most favourable at the sites near Zafarana, Dahab, Ras Sedr, and El Tor, which are estimated to allow yearly productions of 760, 315, 350, and 250MWh respectively for a 225 kW machine; the production prices are given above
- Concerning selling prices - the price paid by the utility, that operates the connecting grid - it is assumed, that in order to be attractive to invest in a wind farm project, private investors expect an IRR of 20%, whereas public investors consider 13.5% reasonable; for a fully imported 225 kW WT, these percentages require a selling price of electricity like 21 pt/kWh for a private investor and 13 pt/kWh for a public

D.2.6 Recommendations

In order to encourage the establishment of wind farms, the working group made the following recommendations:

- The private sector should be encouraged to participate in establishment of wind farms in Egypt
- The local manufacture of wind turbines, private or public, should be encouraged
- The economics of BOOT (Build-Own-Operate-Transfer) concept should be studied, and its benefits to the public and private sectors assessed
- This study - like other - has shown, that larger machines are preferred due to the effect of scale

D.3 References

- Investment & Finance, prepared by eng. Amira El Mallah, NREA, March 1997.

Appendix E Contribution from WG IV, Siting & Application

In this appendix contributions and reports from the Working Group for Siting & Application, WG IV, are compiled along with a short review.

E.1 Tasks

According to the organization of the project, the tasks of this working group are:

* To assess the availability of appropriate sites for wind systems installation. This will involve both resource reviews, needs identification, and land requirement determination. Further, to review assessments of potential wind energy application - grid connected and non-grid connected.

* Responsibilities and activities of this group are:

1. Assess wind energy availability in various potential locations for its utilization
2. Identify candidate areas for wind energy projects
3. Considerate all administrative, legal, and institutional procedures and approvals regarding land ownership, safety, electromagnetic interference, infrastructure, physical planning, environmental assessment, e.g. concerning
   - o impact on birds
   - o visual impact
   - o noise

   To review available wind data for candidate sites, and to identify further need for wind resource assessment:
4. Investigate wind energy potentials in promising areas based on data from NREA and others
5. Prepare plans for evaluation of wind energy availability in different locations
6. Identify the most appropriate and justified locations for wind energy systems

   To identify potential sites for wind projects and evaluate their appropriateness for application, and their required infrastructure, the following tasks are foreseen:

7. Identify and select candidate sites and areas required for wind farm projects
8. Consider institutional procedures, approval of land ownership and access to services, road, telephone lines, etc.
9. Recommend appropriate sites in the areas concerned according to access to services, roads, transmission grid, etc.
10. Assess application options for wind energy systems at location with promising wind resources through different scenarios
11. Recommend priorities and identification of needs for pre-feasibility studies
12. Prepare reports for other WGs for their evaluation of needs to achieve the forecasts
13. Recommend mechanisms for realization of wind energy projects
14. Report to the CG

E.2 Final report by the Working Group

The report considers the availability of appropriate sites for wind energy utilization, i.e., for wind park installations, both regarding grid connected and non-grid connected WTs.

E.2.1 Wind energy resource assessment

During the recent years, an extensive measuring program has been set up in Egypt, particularly in the following regions:

- The Red Sea coast (14 stations)
- The North coast (5 stations)
- Sinai (15 stations)
- New Valley (10 stations)

where wind data are recorded; in some locations the measurements began in 1991. The analysis shows, that the west coast of the Gulf of Suez has extremely good wind conditions; Zafarana belongs to this region.

E.2.2 Utilization of Wind Energy

The study emphasizes, that the Egyptian Ministry of Electricity & Energy, represented by NREA, intends to include in the fourth five-year plan (1997-2002) projects for expanding the capacity of Zafarana wind park by additional 30MW yearly in order to reach a total capacity of 300MW by year 2002.

The report lists a number of demonstration projects aiming at utilizing wind energy in several fields and at different sites:

1. Water pumping at East Oweinat, where a wind diesel system for energizing water pumping for irrigation, comprising a 15kW WT and a 35kW diesel, is operational since 1987.
2. The first demonstration wind farm in Ras Ghareb, where four 100kW WTs have been in operation since 1988.
3. The wind energy ice making plant at Abu Ghusoon, where a wind diesel system with a 55kW WT and a 32kW diesel provides an ice making plant with energy; operating since 1992.
4. The "small" demonstration wind site at Hurghada: a 400kW wind farm containing four 100kW WTs has been installed using several Egyptian produced components; in operation since 1992.
5. The "large" demonstration wind farm at Hurghada: ten Ventis 100kW (operative 1993), twenty Wincon 100kW (operative 1994), and six Nordtank 300kW WTs (operative 1995), have been established in three phases.
6. Electrification and water pumping utilizing wind power in the Northern Coast region: the scope is to establish five wind diesel systems in small villages, each system containing six WTs of 25kW and two diesels of 100kW. The project has been started.

E.2.3 Case studies

Eight regions in South Sinai have been studied, which are assumed to be developed during the coming years, and which therefore need increased amounts of electric energy. The table below gives some main figures concerning the sites.

		Location							
	Year	Ras Sedr	Abu Zenima	Abu Rudies	St. Katreen	El Tor	Sharm el Sheik	Dahab	Niwaba
Peak demand MW	1997	6.8	4.9	4.4	2.2	6.3	5.9	5.3	20.7
	2017	19.65	15.2	5.0	17.8	43.7	53.9	18.6	91.0
Av. wind speed		6.6		4.7	3.4	5.7	5.0	6.3	
Wind cap. MW	2017	13.3				20.0		13.9	

This table shows the potential in the region; due to the wind conditions; in this study, only the most favorable have been analyzed further (Dahab, Ras Sedr, El Tor) by the working group for Investment & Finance.

E.2.4 Conclusions & Recommendations

The report states the following conclusions and recommendations, reached during the work:

E.2.4.1 Conclusions

The study by the working group notes the success of wind energy programs until now, and lists the following essential projects:

- The national wind energy resource assessment program based upon 44 measuring stations has proved the availability of a large wind energy potential in Egypt
- An ambitious Egyptian program has been set up including establishment of a wind farm at Zafarana with a capacity of 600MW in year 2005
- A number of successful wind energy demonstration projects has been carried out or are in progress, such as
  1. Water pumping using a wind turbine at "East Oweinat"
  2. The first demonstration wind farm in "Ras Ghareb"
  3. Wind energy ice making plant at "Abu Ghusoon"
  4. The small demonstration wind site at Hurghada, 400kW wind farm
  5. The large demonstration wind farm in Hurghada
- 6. Electrification and water pumping in Northern Coast region using wind energy

E.2.4.2 Recommendations

The working group recommends that further studies are carried out like:

- Utilization of wind energy in South Sinai, which is a very promising area, should be assessed, because there is a potential demand for electricity in the localities Ras Sedr, El Tor, and Dahab, estimated to be some 47MW in year 2017.
- At other regions, more detailed studies are desirable, e.g., by elaborating a wind atlas for promising sites, and therefore, a priority list for such sites should be set up in order to point out those, that should be studied further.

E.3 References

- Siting & Application Assessment Working Group, Draft Report, prepared by eng.

Laila Georgi, Manager of Wind Department, NREA, and Econ. Adel Mahmoud Ibrahim, Manager of Energy Economics Department, OECP. March 1997.

Appendix F Description of models

In order to calculate consequences of the assumptions that are underlying the scenarios, various types of models have been used. In this appendix a short description will be given of the models:

* the name of the model
* the operator
* the field of application
* the main input
* the main output
* a short overview of the contents of the model and methods used

The following list shows the main characteristics of the models used for this study:

Model	Operator	Fields of	Type	Used for:
BRUS II	NREA	Energy planning	Simulation	All sectors with emphasis on energy and emissions
ES^3	NREA	Power planning	Simulation	Power sector
CashFlo	NREA	Cash flow	Spread Sheet	Levelized Production Costs Internal Rate of Return

In BRUS II and ES3, both the conventional power system and the wind power generation plants are simulated, whereas in "CashFlo", the production by the wind turbines is specified independent of the total power system. Every year is considered in "CashFlo", whereas main results from BRUS II and ES3 are concentrated at selected scenario years. Thus, the models supplement each other, and their results may be considered estimates of various quantities, seen from different point of view - e.g., the electricity production costs; therefore, identical results may not be expected.

In the following, short descriptions are given of each model.

F.1 BRUS II

BRUS II is a simulation model developed to support elaboration of energy plans; it was made to support the Danish energy planning, and therefore contains submodules not relevant to Egypt - they are made inactive. During the first phase of the project, it was transferred from Risø to NREA, implemented on NREA's computers, and adapted to the Egyptian energy system.

F.1.1 Overview

BRUS II can be characterised as a bottom-up model of the energy system. Both demand for energy and supply of electricity are described in detail, representing various technologies. Electricity supply is described as produced from conventional thermal plants and from renewable sources including wind, hydro and solar. In this study, there is special emphasis on the wind energy technologies. Basically, BRUS II contains a scenario projection from a reference year to a medium term year and further to a long term year. Thus, BRUS II illustrates long term perspectives for energy demand and supply as a whole.

It should be noted, that for a detailed, yearly planning of actual expansion plans for wind capacity, e.g., at Zafarana, BRUS II must be complemented by other models like ES3.

Regarding wind aspects, the model estimates consequences like fuel demand, electricity production shared between technologies, and emissions of a specified long term wind expansion plan. This model can be used to illustrate different development paths for wind, if predictions of various parameters like GDP are specified. Because the model is a simulation model, it can not determine any optimal strategy for development of wind capacity.

F.1.2 Fields of application

BRUS II may be used for calculation of consequences of various changes of the energy system, technical as well as economic. In the present context, BRUS II is used - on a sectoral basis - to calculate overall consequences due to different assumptions underlying the various scenarios.

F.1.3 Main inputs

BRUS II contains a large number of data to be specified both for the present situation and for the scenarios. The most important are prognosis for, e.g.:

* demographic data
* GDP
* housing by category
* specific energy demands
* fuel prices
* implementation of new technologies, including wind power

In addition, BRUS II contains a detailed specification of the power production plants, including existing as well as new, described by their characteristics like

* capacity
* fuel
* efficiency
* emissions
* availability
* specific O&M costs
* life time
* yearly full load operation hours, see below

F.1.4 Main outputs

For the scenario years specified, the model calculates

* Energy demand per sector
* Fuel demand per sector
* Costs
* Investments
* Emissions

F.1.5 Methods and contents of the model

BRUS II is a point-model, as the model contains no geographical representation. The model is used to set up scenarios including both demand side and supply side options. Figure 24 gives an overview of the elements of the model.

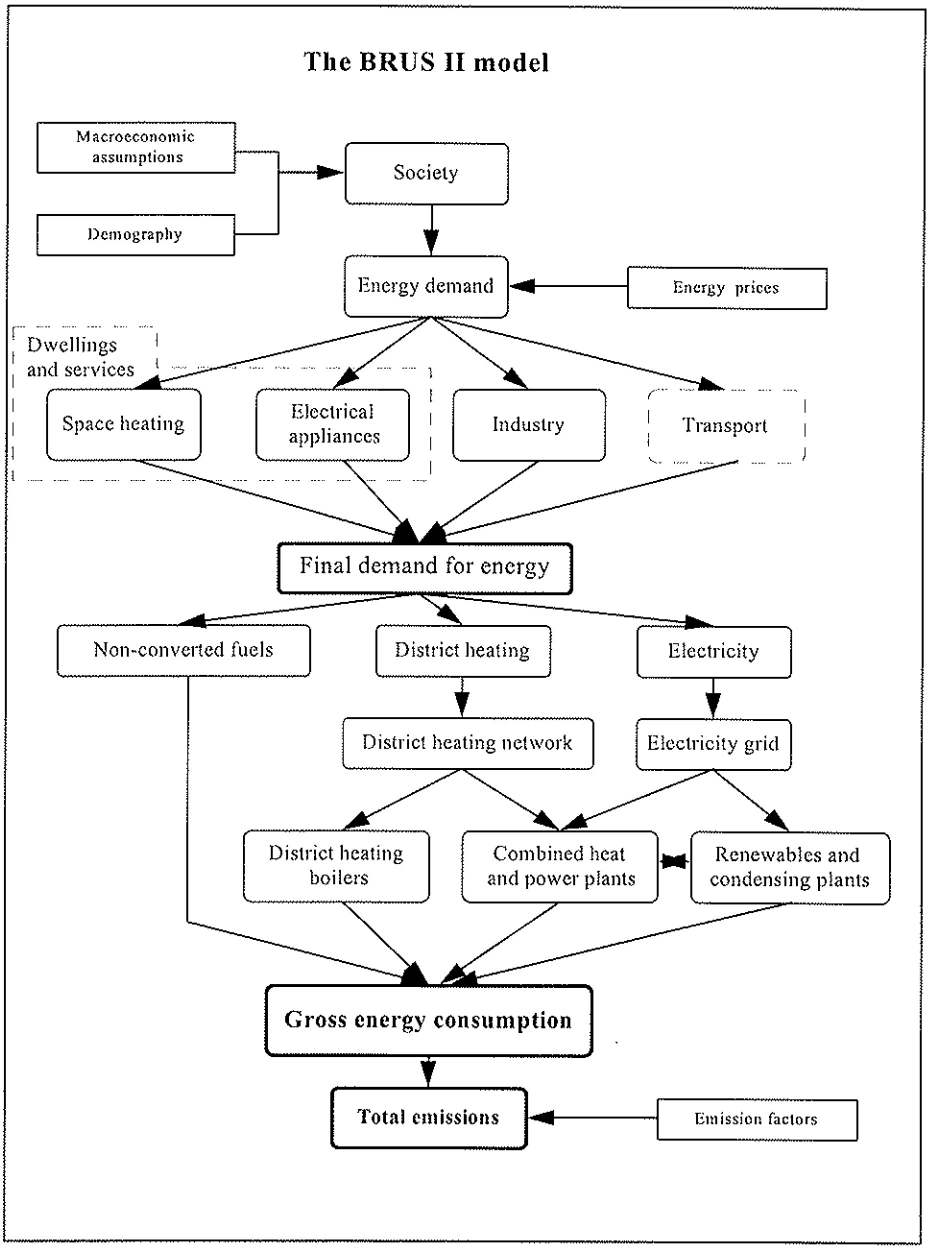

Figure 24 Block diagram of BRUS II

It is organised as a spreadsheet model using Quattro Pro as the basic tool; it is quite easy to convert the model to e.g. EXCEL. The model consists of 24 sheets, each with its particular task; some are primarily input sheets and other are primarily output sheets. As a bottom-up model, demand for energy is determined for different demand categories like:

* Household demand for heat and hot water (not active)
* Household demand for power for electric appliances
* Service sector demand for electricity
* Industrial demand for energy for processes, specified for four sectors
* Transport energy demand

Each of these demand categories are specified independently and contain different assumptions. Household demand depends on projections of population, number of persons per household, new dwellings and saturation degrees for represented appliances. Service sector energy demand is primarily exogenous, like transport energy demand. Industrial demand depends both on production and on fuel prices, both represented by elasticities.

Electricity is produced by a number of plants, which are specified by their capacity, availability, fuel type, fuel efficiency, emission data, and economic quantities like Operation & Maintenance costs, and investments.

The main outputs from specified scenarios are the total energy and electricity demands, which form the basis for calculations on electricity production, resulting fuel demands, production costs, and emissions.

F.1.6 Interface to ES3

BRUS II interchanges data with ES3 concerning the power plants - including wind farms - and the actual power production by various categories of plants (hydro, wind power, combined cycle, steam plants, gas turbines, etc.), and for this purpose an interface has been implemented used for scenario calculations, that combine the two models (manually, however!).

BRUS II determines the available capacity of each technology, that are represented in the scenario and the total electricity demand, and sorts the plant categories into a priority list; the capacity of each category is transferred to ES3, that calculates the full load operation hours for every category, which then are put back into BRUS II, that finally calculates consequences like fuel production by each plant, fuel consumption, economic consequences, etc.

There is one exception between the Full Load Operation Hours - FLOH - calculated by ES3, and those, which are inserted in the interface module of BRUS II: the ES3-FLOH for Steam Turbines must be corrected as follows: for this category, the FLOH found in ES3 must be multiplied by the ratio of the capacities used in the two models before being inserted in BRUS II, i.e., by the factor

Capacity (ES3) / Capacity (BRUS II) for *steam turbines*

The reason is explained in the ES3 report written by eng. Ashour Abdel Salam Moussa and L.H.Nielsen: the category of power plants characterised as Steam Turbines is - inside the ES3 model - reduced (by a fraction of its capacity, that now is regarded like reserve capacity), and the resulting FLOH, corresponding to this reduced capacity, must be related to the capacity of the same category inside BRUS II, in order that the energy generated of this category is correct, and also, that the total generated energy corresponds to the demand. Refer to Table XXXVI for an example of the two capacities.

The BRUS II model has an option to choose between two types of priorities: a *technical priority list* and an *economical priority list.*

Technical priority list: The technical priority list sorts the plants after the plant types. This list can – as an example – be used when the planning authority gives certain types of plants a high priority, e.g. plants using a certain fuel. The user must provide each power unit or unit group with a priority number.

Economical priority list: The economical priority list sorts the plants after the variable costs of the plants, i.e. the operation, the maintenance and the fuel costs. This list reflects a market economic way of planning.

The priority list is generated by two main macros and five additional sub macros. In the economical priority list the total capacity of the conventional plants is (at present) arbitrarily divided in five equal groups (groups 3–7) in order to place the particular unit in a given group.

In both cases, the plants are arranged in eight groups - technical categories:

1. Hydro, solar, and wave power
2. Wind power
3. Combined cycle plants
4. Steam turbines
5. Gas turbines
6. Pumped storage plants
7. Incineration plants
8. Zero capacity units (A dummy group).

F.2 ES^3

ES^3 is a simulation model for a power system comprising conventional as well as non-conventional electricity producing categories. It was developed to support elaboration of various studies concerning the introduction of renewable energy sources like wind energy. Being developed in Denmark, ES3 has facilities like district heating, that are not relevant to Egypt, and therefore bypassed. During the first phase of the project, ES3 was - like BRUS II - transferred from Risø to NREA, implemented on NREA's computers, and adapted to the Egyptian energy system.

F.2.1 Overview

The ES^3 model is a consequence calculation tool developed at Risø National Laboratory aimed to analyze energy system configurations regarding the actual production, simulating demand and production hour by hour. In the model, the installed capacities and energy conversion are represented in detail in certain capacity groups.

The model can be utilised for technical analysis of a system on an overall level of description based on data on aggregated level. It is a technical simulation model and the model does not include economy nor optimisation.

Interactive and iterative consequence analyses of energy systems can be carried out using the model. The model presents technical key figures of the represented system for the user. Furthermore, the ES^3 model gives interactive graphical overviews of input data as well as results in form of time series and time duration curves for all components in the specified energy system.

The ES^3 model is as a complement to the BRUS II model, which performs further energy, economic, and environmental calculations on the total energy system.

Grids for transmission and distribution of electricity, and for heat and gas have no geographical representation in the present version of the model. Grids are characterised by efficiencies and capacities.

F.2.2 Fields of application

Heat constrained electricity production is included in the model like back pressure units for industrial application and co-generation units for district heating (presently, not relevant for Egypt), that have constraints to steam or heat demands, which determine the generation of electricity; the regulation capability of this electricity production is very limited.

In addition, wind power generated in the system is calculated. This production is fluctuating according to the wind fields in the wind farm areas. Regulation of this production is limited and not desirable. If other production facilities in the system are unable to decrease their production in periods of low demand and high average wind speeds, surplus electricity production can occur in the system - or wind farms must stop some turbines.

One application of the ES^3 model is to determine critical wind power capacities where constraints start to be active in a system of a given configuration. The model can analyze, how the expected electricity system development influence constraints, and how future system configuration could be structured to reduce or remove such constraints.

Questions, that may be answered by ES3, are like:

* How large wind power capacities can be introduced in the system before surplus electricity production occurs, if it is assumed, that all other production capacity have no regulation constraints and do not cause excess electricity production in the system?

* How much wind power can be absorbed in the electricity demand profile directly, and to what extent is surplus electricity produced when wind power production in the system is increased?

The residual electricity demand - i.e., that part of the electricity demand, which must be satisfied by other production than from wind farms - will decrease as the production from wind increases: the contribution by wind produced electricity increases with increased wind penetration [overlap or production in phase with demand, however, with a decreasing slope], but simultaneously also "excess" electricity production increases [even with all conventional plants regulated to their minimum production]; this means, that some wind turbines have to be stopped - an undesirable situation.

F.2.3 Main inputs

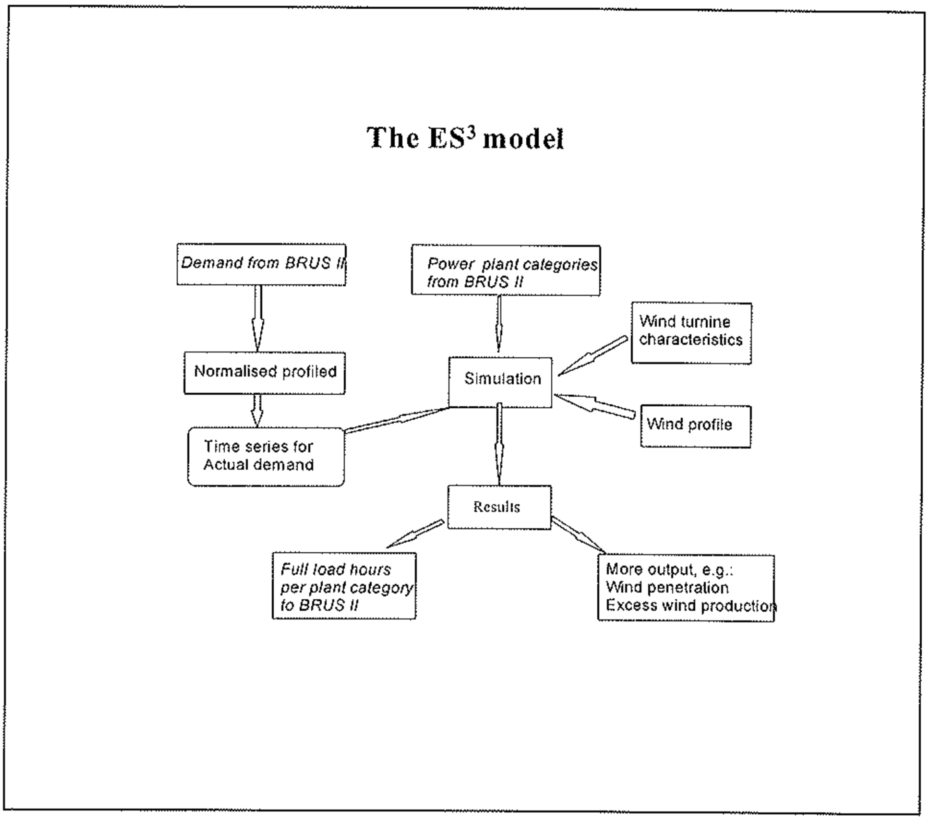

Figure 25 Block diagram of ES3

Data enter the ES^3 model at two levels:

* Basic data are transferred to the ES^3 model system from sub modules, when they are invoked. Sub modules are used to introduce basic assumptions such as wind regime and power curves for the analyses, and they prepare the data structure for the main model.

* Data are entered in the main module during interactive use of the model. Data on demands and technology categories with regulation capability etc. are entered, stored and retrieved in the main module to build up technical scenarios on an overall description level.

F.2.4 Main outputs

The output consists of time series and load duration curves for e.g.:

* power productions of the power plants simulated, given per hour
* load duration curves, especially for the wind power production

In addition, any input and output data may be prepared for hard-copy through various disk files.

F.2.5 Methods and contents of the model

The system simulated with ES^3 comprise a demand side for electricity, heat, and gas, and a supply side for the same energy carriers, including storage for heat and gas. The system can be divided into three levels of production and supply called central, de-central and local and includes interactions between these levels. Refer to Figure 25 for an overview of the model.

The level of description in the ES^3 model can in short be characterised as follows:

* Simulation of energy systems in one hour time steps during a period that typically is chosen as one year. Technical conditions or relations taking place on smaller time scales are not covered by this model.
* Technologies are grouped in categories such as wind turbines, photo voltaic, back pressure plants, extraction plants, condensing plants, gas turbines, fuel cells, electrolysers, gasification plants, heat pumps, resistance heat and dump loads, district heating plants, and energy storage. The categories are characterised by relatively few parameters describing capacity, efficiency, regulation capability, and availability.
* Operation strategies that mainly follow a sequential priority of the production categories based on capacity, efficiency, regulation capability and availability and the desired region for operation in the spectrum from base to peak load. Constraints among technologies and constraints related to demands can furthermore be included in the model.

Technologies are described differently according to their regulation ability. Two main categories are defined:

(1) Fluctuating production, e.g. fluctuating electricity production from wind turbines.
(2) Production with regulation capabilities, e.g. most conventional electricity generation capacity.

In category 1) the production from such technologies is described on the basis of normalised time series that describe the stochastic behaviour of the production.
Category 2) technologies are described on conventional basis. Time series on such production are results of the simulation.

Generally, in this version of the ES^3 model the simulations are carried out on the assumption that all production categories have 100% availability. Inclusion of availability is external the model and require the relevant scaling of installed capacities. Correspondingly, the inclusion of reserve capacity needed in the electricity supply system require relevant scaling of the 100% availability generating capacity categories defined using the ES^3-E model.

F.2.6 Special features of ES^3 for communication with other models

A module has been implemented in ES^3, that enables a transfer of data as time series to EEA models. Further, the interface to BRUS II (part of that model) is used for transfer of data concerning the capacity of each group of power plants, comprising five conventional and two renewable energy plant groups.

F.3 CashFlo

CashFlo is a spread sheet based tool, that is used to calculate Net Present Values, Internal Rate of Return, Levelised Production Price for single wind turbines from cash flow analysis. It is designed at NREA.

F.3.1 Overview

CashFlo is used to estimate the detailed economics for a single project, where components like investments, running costs, and income for sales of electricity to the grid are known. Quantities like inflation rate, capacity factors, and that part of the WT, that could be manufactured in Egypt, are included; further are represented details like insurance, customs, site work, etc. specified.

Time series for a number of variables are calculated, given the planned installation rate, and the resulting cash flow is used to determine the Net Present Value of the project.

F.3.2 Fields of application

Cash flow analysis of the economy of wind farms

F.3.3 Main inputs

* Discount rates
* Exchange rates
* Investments in wind turbines
* Expected life time
* Capacity factor
* Yearly net energy production
* Equivalent consumption of conventional fuel
* Avoided O&M costs in conventional power system
* Investment costs specified in various components
* Running costs: O&M
* Overhaul costs
* Price of sold electricity
* Yearly plan for new WTs

F.3.4 Main outputs

* Yearly and total investments
* Yearly and total running costs
* Yearly and total production and sales value
* Yearly and total fuel savings of conventional fuel
* Discounted cash flow
* Present value of the project

F.3.5 Methods and contents of the model

The spread sheet model utilizes standard methods for analyzing economic time series.

Appendix G Simulations with the models

This appendix contains an overview of the assumptions for and the results of studies and analyses, that have been performed in the model groups using ES^3 and BRUS II - and which are not fully reported in the main text.

Many basic data concerning economical and demographical descriptions of Egypt, that are used in BRUS II, are provided by OECP, while data particular to the power production and distribution systems, and to the electricity production, are provided by EEA. These organizations use these data for their particular analyses; therefore, inside this project, it has been important to check the consistency between the two sources of data in cases, where both organizations use the same type. However, during the period where the analyses were carried out by the working and model groups, the task of securing consistency between data used by the different groups - in particular, when new scenario data were introduced - showed to be a very important, but difficult job.

G.1 Scenario specification

Analysis of the selected scenarios are based on data of the following categories:

- Type of scenario: Two were chosen:
  * *Expected or Base scenario*, meaning a conservative expectation to population and GDP growth; prices constant in real terms
  * *Optimistic scenario* with higher growth rates for population and GDP, but still with constant prices
- Scenario years
  * Reference year
  * Mid term year
  * End Term year
- Locations (Sites, Regions) for planned wind farms:
  * Connected to the national grid: Zafarana
  * Connected to local grids: South Sinai
- Wind turbine characteristics like
  * Capacity
  * Efficiency
  * Life time
  * O&M costs
  * Overhaul costs
  * Initial investments
- Power plant characteristics like
  * Capacity
  * Fuel type
  * Life time
  * O&M costs
  * Initial investments
  * Availability

The results from the analyses are e.g.:

- Fuel consumption and savings
- Emissions
- Fuel costs
- O&M-costs, conventional & wind
- Investments
- Electricity prices, levelised

In the following, some of these data are explained in some detail.

The simulations comprise two main scenarios: A *base case* and a *optimistic case*. The cases are characterised by different projection of yearly GDP and population grow, fuel price increases, and wind penetration. Within each case, various sensitivity analysis have been performed, by variation of projections of fuel price increases and population rates; data are shown in Table XXVII and Table XXVIII.

The projection years have been selected in accordance with other energy planning in Egypt, in order to have consistency in the input data and to be able to compare results. Concerning housing areas related to cooling demand, etc., the partition between old buildings and new was set to year 1980.

Variable	Used for / to specify	Present data
Start year	Starting year of scenario	1992
Midyear	Midterm year of scenario	2017
End year	End year of scenario	2030
Yearold	Partition year of building stock	1980
Monetary unit	Unit that is copied to all sheets	£E
Exchange rate	From US$ to £E	3.4

Table XXVII General scenario data

The general scenario characteristics are given in the next table for the sub cases, that have been analyzed, and some additional data are given in Table XXIX:

	Case:	1992	2017	2030
GDP bill. £	Base	131	287	425
GDP bill. £	Optimistic	131	366	700
Population, mil.	A, B	55,893	85,861	101,477
Population, mil.	C, D	55,893	100,000	135,000

Table XXIX Additional data

G.2 Simulations

	GDP grow yearly %	Wind penetration %	Population rate %	Fuel price increase
Base cases				
A	3.0	7.0	1.7	2.0
B	3.0	7.0	1.7	0.0
C	3.0	7.0	2.3	0.0
D	3.0	7.0	2.3	2.0
Optimistic cases				
A	5.0	14.0	1.7	2.0
B	5.0	14.0	1.7	0.0
C	5.0	14.0	2.3	0.0
D	5.0	14.0	2.3	2.0

Cases B are used as the main scenarios described in the report.

Table XXVIII Characteristics of sub-scenarios

The simulations comprise a combination of BRUS II and ES3, the first takes care of overall technical and economical parts, whereas ES3 analyses the interaction between the various plant categories in detail - as described in appendix F. The two models interact through

* total power demand and available capacities from BRUS II to ES3, and
* full load hours from ES3 to BRUS II,

and in the following, some of these numbers are shown i tabular form. Note, that numbers shown in the main report will not be repeated here. Note also, the values of Full Load operating Hours (FLOH), that are calculated by ES3, have to be adjusted for the 3rd group (steam turbines) due to the special treatment, that ES3 gives it; refer to sec. F.2.

G.2.1 BRUS II simulations

Assumptions used in the calculations are found in the following tables:

-	GDP	Table XXIX
-	Population	Table XXIX
-	Fuel prices	Main report: Table II
-	Power system	
	* Conventional	Table XXXIV
	* Wind	Main report: Table IV and Table V

The BRUS II model needs the *full load operation hours* for the various plant categories in order to compute the energy output of each plant, and from this, the economic and environmental consequences due to energy production are calculated. The ES^3 model generates the full load operation hours using the available capacity of the plant categories, ordered in a priority list, i.e., the priority list determines which plants shall run as base load, and which plants shall run as peak load. The BRUS II model has an option to choose between two types of priorities: a *technical priority list* and an *economical priority list*. The Egyptian case studies have exclusively used the technical priority list. In the following, data for the base scenarios are found in the tables. The groups represented are:

1. Hydro, solar, and wave power
2. Wind power
3. Combined cycle plants
4. Steam turbines
5. Gas turbines
6. Pumped storage plants

Since the ES^3 model need the available capacities, the grouping is also calculated with the availability factors taken into account. The capacity inclusive the availability of the groups is the output to ES^3. The input from ES^3 to BRUS II is the full load hours for the groups.

G.2.1.1 Full load operation hours

In tables Table XXX, Table XXXI, and Table XXXII the data transferred between BRUS II and ES3 are presented, for the reference year and the scenario years, both for the expected and optimistic scenarios and with the two prognoses for the population growth. The *available capacity* is calculated as the *installed capacity* times the *availability* for the particular plant.

Group data 1992	Capacity		From ES3
Number	Installed	Available	Full load h.
1	2715.0	2715.0	4123.0
2	0.4	0.4	3633.0
3	6180.5	5377.0	4500.0
4	283.5	272.2	8760.0
5	2222.7	1711.5	4000.0
6	0.0	0.0	6.0
7	0.0	0.0	0.0
8	0.0	0.0	0.0

Table XXX Reference year 1992

Exp. cases	Total demand (TWh)		
	1992	2017	2030
Pop. growth 1.9% per year	44.6	115.0	186.9
Pop. growth 2.3% per year	44.6	121.8	208.6

Population growth:			1.9%/year	2.3%/year
Year 2017	Capacity		From ES3	
Group #	Installed	Available	Full load h.	
1	2805.1	2805.1	4123	4123.00
2	1800.0	1800.0	3633	3633.00
3	20207.0	17580.1	3096	3477.01
4	5020.8	4820.0	8722	8755.21
5	2044.0	1573.9	36	242.50
6	650.0	624.0	0	8.40
7	0.0	0.0	0	0.00
8	0.0	0.0	0	0.00

Year 2030	Capacity		From ES3	
Group #	Installed	Available	Full load h.	
1	2805.0	2805.0	4123.0	4123.00
2	3250.0	3250.0	3633.0	3633.00
3	38820.0	33773.4	2746.9	3244.83
4	9000.0	8640.0	8751.0	8746.88
5	2000.0	1540.0	163.0	67.50
6	650.0	624.0	6.0	4.50
7	0.0	0.0	0.0	0.00
8	0.0	0.0	0.0	0.00

Table XXXI Expected Cases $\mathbb{A}$ & $\mathbb{B}$

Optimistic cases	Total demand (TWh)		
	1992	2017	2030
Pop. growth 1.9% per year	44.6	135.5	240.8
Pop. growth 2.3% per year	44.6	142.4	262.5

Population growth:			1.9%/year	2.3%/year
Year 2017	Capacity		From ES3	
Group #	Installed	Available	Full load hours	
1	2805.1	2805.1	4123.0	
2	3080.0	3080.0	3633.0	
3	20207.0	17580.1	4006.5	?
4	5020.8	4820.0	8760.0	
5	2044.0	1573.9	143.0	
6	650.0	624.0	6.0	
7	0.0	0.0	0.0	
8	0.0	0.0	0.0	

Year 2030	Capacity		From ES3	
Group #	Installed	Available	Full load h.	
1	2805.0	2805.0	4123.0	
2	5500.0	5500.0	3633.0	?
3	38820.0	33773.4	3964.6	
4	9000.0	8640.0	8760.0	
5	2000.0	1540.0	105.0	
6	650.0	624.0	6.7	
7	0.0	0.0	0.0	
8	0.0	0.0	0.0	

Table XXXII Optimistic Cases C & D

Conventional power plants

The conventional power plants, that are simulated, are specified according to EEA within the representation of BRUS II and ES3; in Table XXXIV planned as well as existing units are listed, mostly characterised by their location, and - after year 2017, which is the last year in the detailed EEA-planning - specified as standard units without location, but the units are necessary in order to substitute old, decommissioned plants.

Results are found in the following tables:

-	Conventional production	Main report: Table VIII, appendix G, Table XXXVI and Table XXXVIII.
-	Wind production	Main report: Table IX, this appendix Table XXXVI and Table XXXVIII.
-	Fuel consumption	Main report: Table VIII
-	Levelised kWh-price	Main report:Table X
-	Investments	Main report:Table XII

Name of plant	Capacity, MW	Start year	Lifetime
Planned STEAM units			
Kureimat st.	650	1997	35
Kureimat st.	650	1998	35
Kureimat st.	650	2006	35
Ayun Mousa st.	325	2001	35
Ayun Mousa st.	325	2002	35
Talkha st.	210	1993	35
Talkha st.	210	1995	35
Sidi krir st. 1	325	1999	35
Sidi krir st. ext.2	325	2000	35
Sidi krir st. ext.3,4	650	2002	35
Damanhour st.	325	2008	35
Cairo West st.	660	1995	35
Cairo West st.	325	2003	35
Cairo West st.	325	2004	35
Assuit Ext st.	300	1996	35
Assuit Ext st.	325	2008	35
Cairo north st.	600	2005	25
Delta north steam	650	2011	35
Delta north steam	650	2012	35
Suez gulf steam	325	2005	35
Ssuez gulf steam	325	2006	35
El daba steam	650	2007	35
Zafarana steam	650	2008	35
Zafarana steam	650	2009	35
Zafarana steam	1300	2010	35
Safaga st.	650	2013	35
Safaga st.	650	2014	35
Safaga st.	650	2015	35
Kafr el dawar st.	650	2016	35
Kafr el dawar st.	650	2017	35

Name of plant	Capacity, MW	Start year	Lifetime
Standard Oil 650 MW	1300	2018	
- - -	1300	2019	35
- - -	1950	2020	35
- - -	1950	2021	35
- - -	1300	2022	35
- - -	1300	2023	35
- - -	1950	2024	35
- - -	1950	2025	35
- - -	1950	2026	35
- - -	1300	2027	35
- - -	1950	2028	35
- - -	1950	2029	35
- - -	3250	2030	35
Planned Gas Turbines			
Cairo north gas turbine	200	2003	20
Cairo north gas turbine	200	2004	20
Mahmoudia gas turbine	300	2009	20
Mahmoudia gas turbine	100	2010	20
Tebbin gas turbine	200	2005	20
Tebbin gas turbine	100	2007	20
Tebbin gas turbine	200	2013	20
Talkha gas turbine	100	2013	20
Talkha gas turbine	100	2014	20
Talkha gas turbine	200	2015	20
Port Said gas	44	1997	21
Karmouz gas turbine	300	2017	20
Standard Gas Turbine 100 MW	400	2019	20
- - -	600	2020	20

Name of plant	Capacity, MW	Start year	Lifetime
Planned Combined Cycle			
Cairo south c.c	165	1995	30
Cairo South c.c	570	1996	25
Mahmoudia c.c	308	1996	25
Damanhour c.c	153	1996	25
Damietta comb.	1125	1993	25
Nobaria c.c	300	2006	25
Nobaria c.c	300	2007	25
Delta north c.c	300	2009	25
Delta north c.c	300	2011	25
Suif c.c	300	2012	25
Suif c.c	600	2014	25
Suif c.c	300	2015	25
Suif c.c	300	2017	25
Standard Combined Cycle 300 MW	1500	2018	25
- - -	300	2019	25
- - -	300	2020	25
- - -	1500	2021	25
- - -	300	2022	25
- - -	300	2023	25
- - -	300	2024	25
- - -	300	2025	25
- - -	300	2026	25
- - -	300	2027	25
- - -	300	2028	25
- - -	300	2029	25
- - -	300	2030	25
Planned Pump Stations			
Attaka pump storage	325	2003	60
Attaka pump storage	325	2004	60

Name of plant	Capacity, MW	Start year	Lifetime
Large existing power plants (<1992)			
Existing STEAM turbines			
Damanhour st	300	1990	35
Walidia st.	300	1992	35
suez steam	97	1991	35
Shoubrah st. 1	315	1984	35
Shoubrah st. 2,3	630	1985	35
Shoubrah st. 4	315	1988	35
Cairo West st. 1,2,3	263	1966	41
Cairo West st. 4	88	1979	35
Kafr El Dawar st.	220	1980	30
Kafr El Dawar st.	110	1984	35
Kafr El Dawar st.	110	1986	35
Abu-kir	300	1983	35
Abu-kir	300	1984	35
Abu-kir	300	1991	35
Ataka st. 1,2	300	1985	35
Ataka st.3	300	1987	35
Ataka st.4	300	1989	35
Abu Soltan st. 1,2	300	1983	35
Abu Soltan st. 3	150	1984	35
Abu Soltan st. 4	150	1986	35
Cairo South st.	240	1957	38
Cairo South st.	15	1965	30
Cairo North st.	70	1952	44
Cairo North st.	20	1955	41
El Tebbin st.	45	1958	40

Name of plant	Capacity, MW	Start year	Lifetime
New Talkha st.	90	1966	42
Old Talkha st.	38	1955	41
New Damanhour st.	195	1968	42
Old Damanhour st.	30	1960	44
Siuf st.	53	1961	43
Siuf st.	60	1969	35
Suez st.	88	1965	40
Assiut st.	90	1966	40
Abu kir ext.	0	1991	35
Ataka	0	1985	35
Ataka	0	1987	35
Ataka	0	1989	35
Existing COMBINED cycle			
Talkha comb.	284	1989	25

Name of plant	Capacity, MW	Start year	Lifetime
Existing GAS turbine			
Damietta gas	750	1989	4
Cairo South gas	330	1989	6
Shabab gas	67	1982	16
Shabab gas	33	1982	21
Mahmoudia gas	196	1983	13
Mahmoudia gas	180	1981	20
Damanhour gas	97	1985	11
Helwan gas	48	1980	15
Helwan gas	24	1980	16
Helwan gas	24	1980	17
Wadi Hof gas	100	1985	20
El Tebbin gas	46	1979	24
Heliopolis gas	38	1980	16
Port Said gas	0	1997	35
Ismailia gas	20	1977	21
Karomuz gas	25	1980	17
El Max gas	28	1966	30
Suez gas	17	1976	20
Siuf gas	67	1981	20
Siuf gas	33	1982	20
Siuf gas	100	1983	20

Table XXXIV Planned and existing conventional power plants

G.2.2 ES3 simulations

Fundamental data and assumptions

Wind profiles are important data, that must be known for the site considered in the analysis; however, due to lack of information, data measured near Zafarana are used in all calculations, normalised to the average wind speed at the particular site, where possible. This approximation is taken as the first step giving an estimate of the production potential.

Demand profiles are as important as the wind profiles, but whereas wind conditions may be regarded constant over many years - varying due to climatic changes and human activities - the overall power demand pattern depends on numerous individual demands, the various sectors having different load patterns, e.g., like the households with TV sets, cooking apparatuses, cooling devices, etc. all with different loads, some running the clock around, others for a few hours only. Thus, a change of the composition of the electric appliances will change the load pattern.

In the project, one load profile only was used, valid for the national grid; this is regarded a first approximation in sites not linked to this system.

Plant categories are basically the same as used in BRUS II, listed in sec. G.2.1.

Main results[13]

Tables are given for the Expected and Optimistic scenarios separately as follows:

Productions per category are presented in Table XXXVI and Table XXXVIII. Note the reserve capacities specified for Steam Turbines.

Full load operation hours - FLOH - are presented in Table XXX, Table XXXI, and Table XXXII.

Particular results

Overflow of production, occurring when it is not possible to decrease conventional production to counteract a high wind production and a low demand in order to keep balance between total production and demand, was not found significant in the simulations, when the wind penetration was increased gradually; even at 20 - 30%, no problems of this character occurred in the simulations.

Specific *grid problems* have not been studied; the transmission grids should be analyzed with specific tools; in this study, it is assumed, that no bottlenecks exist like limited capacities of transmission lines or sub-stations, which implies, that the transmission system is strengthened according to needs.

Expected Scenario

The demand data from BRUS II are shown in Table XXXV and the calculated productions in Table XXXVI.

[13] ES3 data Ref.: Comments on: Draft report from ES3 Model Group, Lars Henrik Nielsen

Demand side

Exp. Scenario	1992			2017			2030		
	MW	h/year	TWh	MW	h/year	TWh	MW	h/year	TWh
Demand	7090	6291	44.6	19361	6291	121.8	33160	6291	208.6

Table XXXV Expected scenario: Assumptions on the overall electricity demand

Supply side

Exp. Scenario	1992		2017		2030	
El. Supply	MW	TWh	MW	TWh	MW	TWh
Cap.ex. reserve in operation:						
Hydro	2715		2805	11.57	2805	11.57
Wind	0.4		1800	6.54	3250	11.81
Combined Cycle	283		5021	42.20	9000	75.57
Steam Turbines	6180		11718	61.12	22833	109.6
Gas Turbines	2222		2044	0.50	2000	0.14
Sum ex.Reserve in operation:		44.6	23388	121.8	39888	208.6
Peak load			19361	0	33160	
Reserve in %[2]			11.5%		10.5%	
Total installed:	11400	44.6	32527	121.8	56525	208.6

[1]: In % relative to peak load

Table XXXVI Electricity supply split on production categories. Scenario: Expected

Optimistic Scenario

The demand data from BRUS II are shown in Table XXXVII, and the calculated productions in Table XXXVIII.

Demand side

Opt. Scenario	1992			2017			2030		
	MW	h/year	TWh	MW	h/year	TWh	MW	h/year	TWh
Demand	7090	6291	44.6	21540	6291	135.5	38280	6291	240.8

Table XXXVII Optimistic Scenario: Assumptions on the overall electricity demand

Supply side

Opt. Scenario	1992		2017		2030	
El. Supply	MW	TWh	MW	TWh	MW	TWh
Cap.ex. reserve in operation:						
Hydro	2715		2805	11.57	2805	11.57
Wind	0.4		3080	11.19	5500	19.98
Combined Cycle	283		5021	42.13	9000	75.57
Steam Turbines	6180		14155	70.44	28562	133.9
Gas Turbines	2222		2044	0.30	2000	0.14
Sum ex.Reserve:		44.6	27105	135.5	47867	240.8
Peak load:			21540	0	38280	0
Reserve in %			11.5%		10.7%	
Total installed:	11400	44.6	33805	135.5	58775	240.8

Table XXXVIII Optimistic Scenario: Electricity supply split on production categories